CLIMATE CHANGE
37/2026

Executive summary

Climate protection measures in coastal ecosystems

Reporting, accounting and financing of Blue Carbon measures

by:

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Abstract: Climate protection measures in coastal ecosystems

In order to achieve climate neutrality, it is essential to not only drastically reduce emissions across all sectors, but also to protect and enhance natural terrestrial and marine carbon sinks. Blue Carbon ecosystems (BCEs) like mangrove forests, seagrass meadows, and tidal marshes are highly relevant and efficient natural carbon sinks. Yet despite their importance, BCEs have long been overlooked as a potential climate solution. Besides storing carbon in biomass and sediments, BCEs offer important and extensive co-benefits like biodiversity support, flood protection and climate adaptation. However, about 50% of BCEs have been degraded since the 20th century, mostly due to the conversion to aquaculture and agriculture, and infrastructure development. Causing the disturbance of carbon-rich sediments, which in turn can lead to CO_2 emissions. With only 2.4% of the ocean being classified as highly protected to date, only 2% of marine carbon stocks are safeguarded - indicating low incentives for protection and potential hurdles of implementation. In order to provide appropriate incentives for protecting BCEs, it is crucial to demonstrate that human interventions can result in additional carbon sequestration. This in turn requires comprehensive knowledge of reporting and accounting frameworks in the context of BCEs.

This paper summarises the findings of an UBA-funded research project to analyse financing and accounting approaches for Blue Carbon measures ("Climate mitigation measures in coastal regions and waters - Accounting, crediting and financing of Blue Carbon measures"). It first defines the term "Blue Carbon" (chapter 1; Oeko-Institut; ZMT 2024). Chapter 2 summarises findings on the climate mitigation potential of Blue Carbon ecosystems, implemented measures and the role of Blue Carbon in international climate policy (Oeko-Institut; ZMT 2024). Chapter 3 summarises an assessment of existing Blue Carbon projects carried out under the research project (ZMT; Oeko-Institut 2025). Chapter 4 discusses findings on available funding approaches and an analysis of associated risks and opportunities (Oeko-Institut; IfW 2025). Chapter 5 discusses questions related to carbon accounting of Blue Carbon activities, including relevant IPCC reporting guidelines and opportunities to expand reporting (Oeko-Institut; ZMT 2024; UBA 2025a; UBA 2025b) and accounting of related activities. Chapter 6 draws overarching conclusions.

Kurzbeschreibung: Klimaschutzmaßnahmen in Küstenregionen und Gewässern – Bilanzierung, Anrechnung und Finanzierung von Blue-Carbon-Maßnahmen

Um Klimaneutralität zu erreichen, ist es neben drastischen Emissionsreduktionen in allen Sektoren auch notwendig, natürliche terrestrische und marine Kohlenstoffsenken zu schützen und ggf. zu erweitern. Blue-Carbon-Ökosysteme (BCEs) wie Mangrovenwälder, Seegraswiesen und Salzwiesen sind bedeutende und effiziente natürliche Kohlenstoffsenken. Trotz ihrer Bedeutung wurden BCEs lange Zeit als potenzielle Klimalösung übersehen. Neben der Speicherung von Kohlenstoff in Biomasse und Sedimenten bieten BCEs auch wichtige und vielfältige Zusatznutzen wie die Förderung der Biodiversität, den Küstenschutz und die Anpassung an den Klimawandel. Seit dem 20. Jahrhundert wurden jedoch etwa 50 % der BCEs degradiert, hauptsächlich durch Umwandlung in Aquakultur und für Landwirtschaft und Infrastrukturentwicklung. Mit der Folge, dass kohlenstoffreiche Sedimente gestört werden, was wiederum zur Freisetzung von CO_2 führen kann. Nur 2,4 % der Ozeane stehen unter strengem Schutz, was lediglich 2 % der marinen Kohlenstoffvorräte sichert - was auf geringe Anreize für den Schutz und potenzielle Hindernisse bei der Umsetzung hindeutet. Um geeignete Anreize für den Schutz von BCEs zu schaffen, ist es notwendig, die durch Interventionen zusätzliche Kohlenstoffbindung zu nachzuweisen. Dies erfordert umfassende Kenntnisse über den Berichts- und Bilanzierungsrahmen im Kontext von BCEs.

Dieser Bericht fasst die Ergebnisse eines vom Umweltbundesamt (UBA) geförderten Forschungsprojekts zur Analyse von Finanzierungs- und Bilanzierungsansätzen für Blue-Carbon-Maßnahmen zusammen („Klimaschutzmaßnahmen in Küstenregionen und Gewässern – Bilanzierung, Anrechnung und Finanzierung von Blue-Carbon-Maßnahmen“). Zunächst wird der Begriff „Blue Carbon“ definiert (Kapitel 1; Öko-Institut; ZMT 2024). Kapitel 2 fasst Erkenntnisse zum Klimaschutzpotenzial von Blue-Carbon-Ökosystemen, zu umgesetzten Maßnahmen sowie zur Rolle von Blue Carbon in der internationalen Klimapolitik zusammen (Öko-Institut; ZMT 2024). Kapitel 3 enthält eine Bewertung bestehender Blue-Carbon-Projekte, die im Rahmen des Forschungsprojekts durchgeführt wurde (ZMT; Oeko-Institut 2025). Kapitel 4 diskutiert Erkenntnisse zu verfügbaren Finanzierungsansätzen sowie eine Analyse der damit verbundenen Risiken und Chancen (Oeko-Institut; IfW 2025). Kapitel 5 behandelt Fragen der Kohlenstoffbilanzierung von Blue-Carbon-Aktivitäten, einschließlich relevanter IPCC-Berichtsrichtlinien und Möglichkeiten zur Erweiterung der Berichterstattung (Oeko-Institut; ZMT 2024; UBA 2025a; UBA 2025b) sowie der Bilanzierung entsprechender Aktivitäten. Kapitel 6 zieht übergreifende Schlussfolgerungen.

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List of abbreviations

BC	Blue Carbon
BCE	Blue Carbon ecosystem
BCP	Blue Carbon project
BTR	Biennial Transparency Report
CAR	Carbon accumulation rates
CCQI	Carbon Credit Quality Initiative
CDM	Clean Development Mechanism
CO_2e	Carbon dioxide equivalent
COP	Conference of the Parties
CP	Carbon pool
CSR	Corporate social responsibility
DIC	Dissolved inorganic carbon
DNS	Debt-for-nature swap
EEF	Exclusive Economic Zone
ERR	Emission reduction and removal
ES	Emission source
ETF	Enhanced Transparency Framework
FPIC	Free, prior and informed consent
FullCAM	Coastal wetlands Full Carbon Accounting Model
GBFF	Global Biodiversity Framework Fund
GCF	Green Climate Fund
GEF	Global Environmental Facility
GHG	Greenhouse gas
IC-VCM	Integrity Council for the Voluntary Carbon Market
IOC-UNESCO	Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization
IPCC	Intergovernmental Panel on Climate Change
ITMO	Internationally transferred mitigation outcome
IUCN	International Union for the Conservation of Nature
LDCF	Least Developed Countries Fund
LULUCF	Land use, land use change and forestry
MDBs	Multilateral Development Banks
MPA	Marine protected area
MS	Member State
NbS	Nature-based solution
NDC	Nationally Determined Contributions (in Paris-Agreement)
ODA	Official Development Aid

BC	Blue Carbon
PES	Payments for Ecosystem Services
PFP	Project Finance for Permanence
REDD	Reducing emissions from deforestation and forest degradation
SCCF	Special Climate Change Fund
SDG	Sustainable Development Goal
UNCLOS	United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change
VCM	Voluntary Carbon Market
VCS	Verified Carbon Standard
WTP	Willingness to pay

1 Introduction and Definition of Blue Carbon

The Paris Agreement aims to limit global warming to well below 2°C and to pursue efforts to keep it below 1.5°C. However, current NDCs are insufficient to meet these targets (UNFCCC 2021). In 2020, the EU adopted the European Climate Law, setting a goal of net-zero GHG emissions by 2050. Climate neutrality mainly requires reducing emissions across sectors and protecting ecosystems. As some emissions are unavoidable (e.g., from agriculture), CO_2 removal through natural sinks in terrestrial and marine ecosystems becomes essential for achieving climate neutrality targets. From 2012 to 2021, these global ocean and land sinks absorbed about 50% of anthropogenic CO_2 emissions (6 GtC/year) (Friedlingstein et al. 2022).

This summary report puts a focus on Blue Carbon ecosystems (BCEs), more specifically on mangroves, seagrasses, and saltmarshes, due to their high relevance as natural carbon sinks. Besides storing carbon storage in biomass and sediments, BCEs also offer important and extensive co-benefits like biodiversity support, flood protection and climate adaptation. However, about 50% of BCEs have been degraded since the 20th century (Li et al. 2018), mostly due to conversion to aquaculture and agriculture, and infrastructure development (Macreadie et al. 2017; Pendleton et al. 2012). Especially, the disturbance of carbon-rich sediments can lead to CO_2 emissions. Only 2.4% of the ocean is highly protected, safeguarding just 2% of marine carbon stocks (Atwood et al. 2020).

There is currently no universally accepted definition of Blue Carbon (BC) that has been scientifically or politically been agreed upon. The term was originally coined in a rapid assessment report by the United Nations Environment Programme (UNEP), which described the atmospheric carbon that is captured by marine living organisms and stored in sediments of vegetated coastal ecosystems like mangrove forests, tidal marshes and seagrass meadows (Nelleman et al. 2009). The term was used to differentiate carbon sequestered by marine plants (“Blue Carbon”) and by land plants (“green carbon”), both taking up "brown carbon" from the atmosphere. It is predominantly used in relation to carbon sequestration in mangrove forests, seagrass meadows and tidal marshes.

For the context of the present research project, the following working definition of BC has been developed, which takes the marine origin of the carbon and important pools into account (see (Oeko-Institut; ZMT 2024):

Blue Carbon refers to the carbon captured by marine organisms and stored in living and dead biomass as well as in organic compounds in the sediment.

Measures that aim to manage BC fluxes (BC measures) must have a positive effect in terms of climate change mitigation and meet the following criteria (Oeko-Institut; ZMT 2024):

1. The BC measures reduce anthropogenically-caused emissions and positively affect net carbon capture and storage in a marine ecosystem in a time frame of at least several decades.
2. BC measures must be accompanied by an appropriate monitoring of carbon fluxes in order to demonstrate significant (I) carbon uptake and (II) carbon storage in the habitat, as well as of (III) the influence of human activities on carbon sequestration.
3. To ensure that BC measures also deliver additional benefits for biodiversity and society, BC measures must additionally be aligned with the concept of nature-based solutions (NbS).

In recent years, BC has increasingly been used as an umbrella term for climate mitigation measures that are related to the ocean (IPCC 2019a), especially in the context of achieving national climate goals and in voluntary carbon markets (IUCN; The Nature Conservancy 2016;

Taraska 2018). Yet, while public interest in BC ecosystems has been increasing and some recovery has been observed over the past decades, full restoration of ecosystem structure and function remains unachieved. Substantial costs involved in restoration projects necessitate significant investment and as the immediate economic returns can be limited, securing funds and encouraging participation in these activities has proven to be challenging (e.g. Shusheng et al. 2023).

Mobilising additional resources for NbS remains a priority for national governments and multilateral cooperation alike. As public funding sources are scarce, the search for additional sources also includes non-traditional policy options such as leveraging contributions from the private sector (UNEP 2023). In response, the integration of coastal ecosystems into carbon markets – so-called "Blue Carbon projects" – has been proposed as a funding strategy. These projects aim to generate carbon credits by conserving or restoring carbon-rich coastal ecosystems, theoretically linking protection with market-based climate mitigation. However, while such projects are often promoted as "win-win" solutions, their actual implementation reveals a wide range of practical, technical, and ethical challenges. In particular, concerns exist regarding the robustness of carbon accounting methods, the permanence and additionality of mitigation impacts and the adequacy of social safeguards. If such concerns are not properly addressed, Blue Carbon credits may lack integrity. If BC credits with low integrity are used to compensate for emissions elsewhere, this may ultimately undermine mitigation efforts as it could lead to a net increase in global emissions.

This paper summarizes the findings of an UBA-funded research project that analysed financing and accounting approaches for Blue Carbon measures ("Climate mitigation measures in coastal regions and waters - Accounting, crediting and financing of Blue Carbon measures"). Chapter 2 presents an overview of Blue Carbon activities and findings regarding the climate change mitigation potential of Blue Carbon ecosystems, as well as the role of Blue Carbon in international climate policy (Oeko-Institut; ZMT 2024; UBA 2025a). Chapter 3 summarises an analysis and assessment of existing Blue Carbon projects, examining the chances, risks and potential success factors of Blue Carbon projects within voluntary carbon markets (ZMT; Oeko-Institut 2025). Chapter 4 provides an overview of available funding approaches for Blue Carbon activities, and compares risks and opportunities associated with the use of carbon credits to those of other potential funding sources (Oeko-Institut; IfW 2025). Chapter 5 discusses questions related to carbon accounting of Blue Carbon activities, including relevant IPCC reporting guidelines and potential opportunities to expand reporting (Oeko-Institut; ZMT 2024; UBA 2025a; UBA 2025b) and accounting of related activities. Chapter 6 draws overarching conclusions.

2 Current Status and Climate Change Mitigation Potential of Blue Carbon[1]

2.1 Overview of Blue Carbon activities

The possible activities aiming at protecting or increasing carbon sequestration and storage in coastal ecosystems are manifold and differ depending on the coastal ecosystem type as well as their site condition and previous management regime, which in turn are largely dependent on local conditions. The interventions to protect and enhance carbon sequestration need to address both, direct and indirect pressures.

Mangrove forests, tidal marshes and seagrass meadows have emerged as those coastal ecosystems that meet the majority of the criteria which account for long-term removal and storage of CO_2 on the one hand, and for the practicality of management activities on the other hand (Lovelock and Duarte 2019), and are considered the "established solutions" which current debates are centred upon.

- *Mangrove forests* - Activities include conservation of intact mangrove forests, restoration through hydrological reconnection and replanting (López-Portillo et al. 2017; Alongi 2014). Additional activities are sustainable management practices that maintain ecosystem function and resilience and policies, such as the establishment of protected areas and the integration of mangrove forests into national climate strategies support long-term carbon storage.
- *Tidal Marshes (or saltmarshes)* - Restoration focuses on re-establishing the hydrological regime by removing barriers and opening dikes seasonally to allow for regular flooding of the marsh area. This increases salinity and reduces methane emissions substantially (Kroeger et al. 2017). Regular flooding causes sediment inflow and enhances allochthonous carbon storage (van den Hoven et al. 2022). Other restoration measures involve planting, fertilization, and sediment addition.
- *Seagrass meadows* - The global decline of seagrass and the need for seagrass conservation are long known (Waycott et al. 2009; Unsworth et al. 2022; Unsworth and Cullen 2010). Yet, seagrass restoration is challenging because of the dynamic and stressful environment seagrasses often grow in. To restore seagrass meadows, planting of seagrasses or spreading seeds is necessary. Both are labour-intense as they require the use of divers. In addition to the site conditions, the success of these measures depends largely on the size of the area and the time frame. Dense vegetation promote autochthonous carbon sequestration, and where terrestrial carbon can flow, sequestration can be maximised (Duarte et al. 2013).[2]

2.2 Climate Change Mitigation Potential of Blue Carbon

Following increased scientific and societal awareness, research activities on the potential of marine ecosystems for climate change mitigation have increased. Despite improvements in quantifying BC, large uncertainties remain regarding spatial and temporal dimensions and the climatic cost-effectiveness of BC measures (Gattuso et al. 2021; Williamson and Gattuso 2022).

While BC quantification is expertise- and resource-intensive, the development of a standardized protocol in the “Blue Carbon Manual” (Howard et al. 2014) contributed to the production of

[1] Please refer to Oeko-Institut; ZMT (2024) and ZMT; Oeko-Institut (2025) which this chapter is based on for further details.

[2] However, a sequestration of very large amounts of allochthonous carbon may also have negative effects on seagrass meadows due to eutrophication and hypoxia and ultimately result in the release of CO_2 emissions.

relevant data sets, improved data comparability and reduced effort. Many studies have assessed carbon stocks in BCEs and the current understanding of carbon storage is largely based on carbon stock calculations and CO_2 release scenarios, focusing on avoided emissions through BCE conservation (Jennerjahn 2021). It has to be noted that carbon stocks do not provide information on actual carbon accumulation rates, in contrast to sediment core age dating by measuring radioactive isotopes, which is costly and sensitive to physical disturbances. Accordingly, the global carbon accumulation rates dataset remains small compared to stock data sets. This highlights a discrepancy in our understanding of how much carbon is actively sequestered over time rather than simply stored. Carbon stocks and carbon accumulation rates describe different sequestration aspects. Stocks show stored carbon and vulnerability potential; carbon accumulation rates indicate actual mitigation potential through long-term CO_2 removal (Jennerjahn 2021).

The quantification of BC on a global scale is hampered by scientific and technical constraints, including: i) high local variability due to environmental factors; ii) unknown source composition of the deposited carbon (high, variable shares of allochthonous carbon complicate attribution); iii) insufficient data on carbon losses through export and decomposition; iv) poorly understood methane and nitrous oxide emissions.

According to available estimates, BCEs store 0.216 Gt CO_2/year , which accounts for < 1% of annual global emissions (Friedlingstein et al. 2022). Restoration of an additional 18–32 million hectares of BCEs could increase carbon drawdown by up to 0.841 Gt CO_2/year, potentially making up for a removal of up to 3% of global annual emissions (Macreadie et al. 2021). However, most of this potential is from actions to counteract the continued degradation of BCEs and thereby protect existing carbon stocks (avoided CO_2 emissions). It should be noted, that the contribution of BC is estimated differently by various studies, ranging from 0.02% to 6.6% of global annual emissions (Williamson and Gattuso 2022).

While awareness of the multitude of ecosystem services provided by BCEs is growing and as well as initiatives to conserve and restore these ecosystems are growing, annual area loss rates are still in the order of 1-2 % for tidal marshes (Duarte et al. 2008) and seagrass meadows (Waycott et al. 2009), while they are 0.2-0.4% for mangrove forests (Friess et al. 2019). BCEs are vulnerable to the impacts of climate change, particularly to warming, marine heat waves, sea level rise and an increase in frequency and intensity of extreme weather events (Cooley et al. 2022). However, human activities like deforestation, pollution, eutrophication, siltation, overexploitation (e.g. timber, fishing) and changes in hydrology, pose an even greater threat to the existence and wellbeing of coastal BCEs. These threats not only have negative impacts on the resilience and biodiversity of BCEs, but can also cause significant emissions, thus limiting the mitigation potential of BCEs.

2.3 Role of Blue Carbon in International Climate Policy

The definition of the climate system in the UNFCCC encompasses the hydrosphere and therefore also the oceans (Article 1.3). The sustainable management, conservation and enhancement of oceans, coastal and marine ecosystems are part of the commitments under Article 4.1.(d). The UNFCCC establishes obligations for Parties within their national jurisdictions, including their Exclusive Economic Zone (EEZ) as defined by the UN Convention on the Law of the Sea (UNCLOS). Of the two instruments with legal force under the Convention, the Kyoto Protocol, and the Paris Agreement, only the Paris Agreement explicitly mentions oceans. Article 5.1 obliges Parties to “conserve and enhance, as appropriate” sinks and reservoirs included under Article 4.1.(d), though it primarily focuses on forests.

COP25 mandated one Ocean and Climate Change Dialogue "to consider how to strengthen adaptation and mitigation action", which took place in 2020 (SBSTA 2021). COP26 extended this by mandating annual dialogues, and COP27 introduced co-facilitators for a two-year term. The first co-facilitated dialogue in 2023 focused on coastal restoration and Blue Carbon. Beyond mandating dialogues, COP27 also encouraged Parties to consider ocean-based action in NDCs and long-term strategies. Ocean-based action includes not only ecosystems and Blue Carbon, but also ocean-based energy, transport, and fisheries. Dedicated advocacy and diplomacy from Parties and Observers preceded this enhanced attention on the role of oceans under the UNFCCC. In 2015, 23 Heads of State signed the first "Because the Ocean Declaration" before the start of COP21 (Because the Ocean 2015). The initiative highlighted ocean vulnerability, as well as its ecological and economic importance and called for an "Ocean action plan." A second declaration followed at COP22; the third in 2021 aimed at an ocean-related outcome at COP26. As of 2024, 41 countries have signed the declaration, including 10 EU Member States (Because the Ocean 2024). COP28 marked an important milestone and referenced oceans several times in the Global Stocktake outcome, encouraging Parties to "preserve and restore oceans and coastal ecosystems" and scale mitigation actions. It also noted the benefits of ecosystem-based adaptation. The Global Climate Action Agenda[3] includes Oceans and Coastal Zones as a thematic area, with a 1.5°C-aligned pathway calling for protection of >30% of oceans and investment in 17 Mha of mangroves by 2030.

As of April 2024, 56 Parties include a reference to Blue Carbon ecosystems in their NDCs (Oeko-Institut; ZMT 2024).[4] The majority of Parties are developing countries (12 from Africa, 24 from Asia-Pacific, 15 from Latin America and the Caribbean). Only four developed countries include a reference to Blue Carbon ecosystems in their NDCs[5]. References can be categorized into three categories: 1) statements, e.g. related to the importance of Blue Carbon ecosystems and the ocean, as well as expected impacts; 2) proposed policies and measures and 3) targets. NDCs refer to coastal wetlands, marine ecosystems, mangrove forests, seagrass meadows and coral reefs. These references mainly focus on mitigation and adaptation at the same time or are explicitly related to adaptation. In terms of mitigation, Parties refer to carbon sequestration; reducing emissions from ecosystem conversion is less prominent. Another focus is on research and monitoring as countries propose to strengthen research and implement monitoring programmes. 39 countries have proposed quantified targets. The most common targets relate to the protection or the conservation of ecosystems, which includes strengthening institutional arrangements for protection and management. The majority of countries include references to Blue Carbon in their NDCs regarding the implementation of specific policies and measures in these ecosystems.

Other UN processes address Blue Carbon, notably SDG 14 and the UN Ocean Conference in Lisbon 2022, which stressed the role of NbS. A draft agreement under UNCLOS on marine biodiversity beyond national jurisdiction was reached in 2023. The UN Ocean Decade (2021–2030) promotes science, funding, and partnerships, supported financially by the Governments of Norway, Sweden, Japan, Canada, and Portugal. Action under the Ocean Decade is organized around ten challenges, while two challenges are directly related to climate solutions and ecosystem restoration.

[3] Formally known as the Marrakech Partnership for Global Climate Action.

[4] Key words used to find references in NDCs: ocean, marine, blue, mangrove. 45 countries include more than one reference in their NDC; 11 countries include only one reference.

[5] These four countries are Australia, Canada, the US, and the UK. Australia, the EU, the UK, the Republic of Korea and Norway also state that they intend to use the 2013 IPCC Wetlands supplement for their GHG reporting.

3 Analysis of Existing Blue Carbon Projects in the Voluntary Carbon Market[6]

3.1 Landscape of Blue Carbon Projects in the voluntary carbon market

There are currently four carbon crediting programmes operating on the voluntary carbon market that offer registration of Blue Carbon projects. These are Verra's Verified Carbon Standard (VCS), the Gold Standard for the Global Goals, the Climate Action Reserve (CAR) and Plan Vivo. BC projects currently make up less than 1% of transactions in the VCM, but interest is increasing, with at least 55 BC projects in the pipeline of major carbon crediting programmes. Most of these are seeking registration under the VCS, the largest VCM programme by credit issuance.

The Blue Carbon-relevant knowledge is not as advanced for seagrass meadows and tidal marshes as for mangrove forests. Consequently, there is only one seagrass BCP under development and none for saltmarshes. However, there are numerous research and restoration projects which are aiming at closing the data and knowledge gap and/or exploring opportunities for Blue Carbon in restoration projects.

An overview of BC projects registered and under development is provided in Table 1.

Table 1: Number of BC projects registered and under development

Program	Registered	In project pipelines
Clean Development Mechanism[7]	1	0
Climate Action Reserve	2	NE*
Gold Standard	0	0
Plan Vivo	3	8
Verified Carbon Standard (VCS)	11	47
Total	**17**	**55**

Sources: Registries of carbon crediting programmes. Information as of 30 September 2024.
*The registry does not allow to filter for the project type mangrove restoration. Hence, no information could be retrieved on the number of projects in the pipeline.

For registration, project developers must estimate the emission reduction and removal impact of their projects by applying a quantification methodology that is eligible under the respective carbon crediting programme. Currently, about half of the registered projects have applied the CDM methodology AR-AM0014. With a project pipeline of 29 projects, VM0033 is poised to become the most important methodology for quantifying BC projects. Released in August 2024, the market uptake of the Gold Standard Methodology for Sustainable Management of Mangroves is yet to be determined. The same applies for the Panama and Guatemala Forest Protocols eligible for certification under the Climate Action Reserve. An overview of the existing quantification methodologies is given in Table 2.

[6] Please refer to ZMT; Oeko-Institut (2025) which this chapter is based on for further details.

[7] BC projects were eligible for registration under the Clean Development Mechanism (CDM) until 31.12.2020.

Table 2: Quantification methodologies eligible under carbon crediting programmes

Methodology	Release year of first version	Eligible under	Projects registered	In project pipelines
AR-AM0014	2011	CDM, VCS	9	6
GS Sustainable Management of Mangroves	2024	Gold Standard	0	0
Plan Vivo Standard	2014	Plan Vivo	3	8
Mexico Forest Protocol	2013	Climate Action Reserve	2	NE*
Panama Forest Protocol	2024	Climate Action Reserve	0	0
Guatemala Forest Protocol	2024	Climate Action Reserve	0	0
VM0007	2011	VCS	2	12
VM0033	2015	VCS	1	29
Total			**17**	**55**

Sources: Registries of carbon crediting programmes. Information as of 30 September 2024.
*The registry does not allow to filter for the project type mangrove restoration. Hence, no information could be retrieved on the number of projects in the pipeline.

3.2 Assessment of existing Blue Carbon Projects

Based on the existing landscape of BC projects, a project sample was selected to analyse projects regarding the five dimensions of additionality, quantification, permanence, environmental and social impacts, and double counting. These dimensions cover aspects that are of key importance for the environmental integrity of carbon credits and build on the indicators of existing assessment frameworks such as the Core Carbon Principles of the Integrity Council on the Voluntary Carbon Markets (IC-VCM) and the assessment methodology of the Carbon Credit Quality Initiative (CCQI). The final sample for our analysis, which consists of seven projects covers all quantification methodologies with active registrations, ensures regional balance and focuses on mangrove ecosystems, as these are the dominant BC projects, including only one project under development for seagrass meadows and none for saltmarshes. An overview of the main project characteristics is given in Section 3.2 of ZMT; Oeko-Institut (2025). In the following, the results of the assessment of the reviewed project sample is presented.

3.2.1 Additionality

Additionality plays a central role for the concept of carbon credits. Emission reduction and removals (ERRs) are additional "if the mitigation or removal activity would not have taken place in the absence of the added incentive created by carbon credits" (CCQI 2022). Assessing whether a mitigation activity is additional is, however, inherently difficult and requires comparing the activity to a hypothetical baseline scenario without the added incentives of carbon credits, which involves making assumptions about many parameters and is associated with high uncertainty. Even if it is methodologically impossible to determine with 100% certainty whether a project is additional, it is possible to restrict eligibility for participation in carbon crediting to those mitigation activities that have a very high likelihood to be additional. Minimising the risk that project proponents receive carbon credits for non-additional mitigation activities as much possible is crucial for any market-based mechanism as it is a key prerequisite for its environmental integrity. To minimise these risks, carbon crediting programmes can restrict eligibility of activities to those, for which project proponents:

- Are not obliged to implement activities due to legal requirements in the country where the project is proposed to take place (legal requirements). The assessment of the project sample shows that for those projects whose project area intersects with already protected areas, it is important to clearly describe, how the project activities go beyond those that can be plausibly achieved with the protected area status. A crucial requirement as BC projects within protected areas are preferred by many project developers, as it supports continuation of the project activity after the end of the carbon crediting programme.
- Can demonstrate that they have considered revenues from carbon credits at the time when making their investment decision (prior revenue consideration). None of the carbon crediting programmes currently in place require project developers to demonstrate that they have considered revenues from carbon credits at the time when making their investment decision.
- Can demonstrate that additional income from selling carbon credits is required for covering the costs of these activities and/or for mobilising funders that are willing to invest in them (financial attractiveness);

  OR;
- Can demonstrate that the project activities face non-financial barriers that can be overcome with the help of the carbon crediting mechanisms (barriers).

Most carbon crediting programmes have provisions in place that restrict eligibility along the three aspects presented above. They typically set out these eligibility provisions in their overarching standard documents which contain the general rules that project proponents must follow for registering a project. Some programmes add specific requirements for certain project types, typically contained in the project type specific quantification methodology. Their stringency however differs, as summarized in Table 3.

Table 3: Summary table: Overview of additionality provisions of carbon crediting programmes

	Climate Action Reserve Mexico Forest Protocol	**Plan Vivo Standard** Plan Vivo Standard v.4	**VCS** VM0007 and VM0033	**VCS** AR-AM0014
Legal requirements				
Definition	Law, statute, rule, regulation, or ordinance	Legislation, official policies, regulations, or industry standards	Law, statute, or other regulatory framework	Mandatory applicable legislation and regulations
Scope of exclusion	All legal requirements	Exemptions exist for legal requirements for which project	Exemptions exist for legal requirements for which project	Exemptions exist for legal requirements for which project

	Climate Action Reserve Mexico Forest Protocol	**Plan Vivo Standard** Plan Vivo Standard v.4	**VCS** VM0007 and VM0033	**VCS** AR-AM0014
		developers can demonstrate that they are not systematically enforced	developers can demonstrate that they are not systematically enforced in Non-Annex I countries	developers can demonstrate that they are not systematically enforced
Frequency of demonstration	At each verification	Every 10-years	At each verification and crediting period renewal	At each verification and crediting period renewal
Prior consideration	No requirements	No requirements	No requirements	No requirements
Financial attractiveness/ Barriers	Performance Standard Test	Assessment at project level	Positive list based on applicability conditions	Assessment at project level

Sources: Standard documents of carbon crediting programmes.

Overall, current project documentation would benefit from more stringent requirements to at least conduct a cost comparison analysis, including a disclosure of other relevant funding streams for the project and a demonstration why these streams are not relevant for the proposed activity. This is especially relevant for those BC projects, which intersect with protected areas, as these often rely on multiple funding sources that support conservation efforts. Even if these are not targeted at enhancing carbon storage capacities of mangrove ecosystems, they can still have a positive effect for restoration or protection, which needs to be considered during the additionality assessment. In addition, carbon crediting programmes should consider how they could incentivise implementation of new BC projects outside of protected areas. The main argument of the VCS additionality tool for considering BC projects as automatically additional for example is that less than 5% of wetlands can be considered as protected. If, however, most BC projects take place in protected areas, this argument might no longer hold, and it would be advisable to introduce a mandatory additionality assessment that assesses additionality on a project-by-project basis.

3.2.2 Quantification of mitigation impact

Most climate market mechanisms are based on the idea of turning emission reductions or removals into tradable units to incentivise cost-effective mitigation. These units typically represent one tonne of carbon dioxide equivalent (CO_2e). Ensuring that each carbon credit reliably reflects one tonne of CO_2e is essential for the credibility and functionality of these markets. If trust in this equivalence is lost, the environmental integrity of the mechanism is compromised, potentially leading to higher overall greenhouse gas levels. This is why applying robust approaches for estimating the mitigation impact of a project activity is fundamental.

It is a well established principle that quantification methodologies should follow a conservative approach towards estimating emission reductions and removals, meaning they should err on the side of underestimating emission reductions or removals. The level of underestimation should increase with the degree of uncertainty in the quantification. Judging the conservativeness of a methodology is challenging for three reasons (World Wildlife Fund (WWF), Environmental Defense Fund (EDF), Oeko-Institut 2022):

- Emission reductions and removals are determined against a counter-factual baseline scenario, which is inherently unknown,
- Mitigation activities can involve significant indirect emission changes upstream or downstream of the activity,
- Some elements of a methodology might lead to overestimation of emission reductions and removals, while others might lead to underestimation or uncertainty.

To assess the robustness of a quantification methodology, we assessed the following aspects of methodologies used for the selected projects:

1. The approach to the selection of carbon pools (CP) and emission sources (ES) for calculating emission reductions or removals,
2. The approach to determining baseline emissions,
3. The approach to determining project emissions,
4. The approach to determining leakage emissions.

Overall, the **approach to selecting carbon pools and emission sources** under the different quantification methodologies can lead to overestimation and underestimation of ERRs. The assessed methodologies generally include all relevant carbon pools and emission sources in the greenhouse gas assessment boundary. However, they allow the exclusion of certain minor emission sources, which could lead to overestimations, though likely not substantial. The largest underestimation likely results from the exclusion of the soil organic carbon pool. Given the uncertainties and high costs associated with estimating the effects of mitigation activities on the soil organic carbon pool, an exclusion appears to be an effective strategy to simplify project development without undermining the conservativeness of the quantification. The extent of underestimation might further justify excluding some of the smaller pools and emission sources from the GHG assessment boundary such as, e.g., harvested wood products, fossil fuel use, or nitrification, whose exclusion would result in overestimation. An emission source that currently introduces uncertainty in the overall mitigation impact is methane emissions from microbes. Further research is required to better understand the extent of methane emissions associated with establishing or reforesting mangrove habitats. In the meantime, the uncertainty should be reflected through appropriate uncertainty deductions to ensure conservatives of the calculated net effect of Blue Carbon projects.

Potentially substantial overestimating risks are associated with the approaches to **estimating baseline deforestation rates** in the project subtype of mangrove *conservation* projects. Here, the analysis of the sample projects showed that these projects face similar issues of baseline uncertainty as REDD+ projects in terrestrial forests. The respective methodology offering registration for this subtype, VCS VM0007, does not appropriately account for this uncertainty. In contrast, it provides project developers with considerable flexibility in selecting reference areas and periods for determining baseline deforestation rate. One project in the sample, for example, assumes that baseline deforestation would result in the loss of 67% of mangrove carbon stocks by the end of the project crediting period. Considering that the project takes place in a protected area, this may be a very aggressive assumption. In contrast, mangrove *restoration* projects appear less affected by systemic baseline uncertainty. However, individual projects may overestimate carbon removals if they fail to account for the possibility that restoration might have occurred through alternative funding sources under the baseline scenario. This risk is particularly relevant in areas with a history of successful mangrove restoration activities. Addressing this issue would be relatively straightforward, for example, by requiring project developers to apply conservative deductions to the credited project area in such contexts.

Measuring the effect of project activities on changes in carbon pools occurring between baseline and project scenario is also associated with uncertainty. The lack of long-term data on carbon fluxes, especially in restored ecosystems and for non-mangrove habitats like seagrasses and saltmarshes, makes the estimation of these changes challenging. For biomass carbon accounting, the main uncertainties result from the selection of appropriate allometric equations, the number of sample trees used to construct these equations, as well as location and placement of sample plot design for ex-post measurements of removals. Carbon estimates in all sample projects are affected by these uncertainties. Whether these more likely lead to over- or underestimation in the project sample was inconclusive. Organic soils are by far the largest carbon pool of Blue Carbon ecosystems and at the same time the most difficult to monitor. Obtaining necessary data requires specialised expertise and access to laboratory equipment. Measurement is further associated with high costs and therefore field data are scarce and based on few samples. Moreover, soil carbon samples show high variations between different measurement plots in the same area. Overall, uncertainties around soil carbon accumulation can result in very high over-crediting risks due to the importance of the soil carbon stock for carbon accounting.

Methodologies account for these uncertainties in different ways: The CAR Mexico Forest Protocol does not allow to account for soil carbon accumulation and the CDM methodology AR-AM0014 prescribes using a default factor. Only the VCS methodologies VM0007 and VM0033 provide flexibilities to inter alia use a default factor, factors defined in relevant scientific reports, or field-data collected in the project area. Observations from other project types in carbon markets have shown that this flexibility can lead to overestimation as it may incentivise project developers to pick-and-choose the approach which results in most carbon credits. We, however, found no evidence of such adverse selection in the sample projects. This is because the two projects accounting for soil carbon currently use default factors to determine accumulation rates in a way that very likely underestimates soil carbon stocks.[8] The degree of underestimation likely compensates for any overestimations of the project's climate impact due to uncertainties in estimating biomass carbon stocks or the exclusion of small emission sources associated with the project activities from the greenhouse gas assessment boundary.[9] Yet, overall, soil carbon quantification remains highly uncertain and could lead to overestimation if projects use field-data which are not representative of the full project area or if refined scientific research finds that default values overestimate soil accumulation rates. For future projects, adverse selection due to the flexibility in the VCS methodology could therefore become an issue.

Ecological leakage (changes in GHG emissions from ecosystems that are hydrologically connected to the project area) **and activity-shifting leakage** (shifting of an activity outside the project area that was responsible for GHG emissions) is usually addressed by individual projects as it is required by all three carbon crediting programmes. However, **market leakage** (increase in overall GHG emissions due to changes of behaviour of a wider range of market actors) is only

[8] The project using the VCS default factor, conservatively accounts for allochthonous carbon, the portion of carbon stored in soils that does not result from local CO_2 uptake. The other project uses the CDM default factor, which may be conservative for many key geographic regions hosting mangrove habitat, although it is unclear if it already includes a deduction for allochthonous carbon. Further analysis would therefore be required to assess whether applying this factor would generally lead to conservative estimates. The degree of underestimation in the project using the VCS default factor coupled with allochthonous carbon deductions using a scientific deduction procedure is likely to be high.

[9] It is important to note that these observations are based on the approaches applied by two sample projects and therefore do not allow for general conclusions on the conservativeness of soil carbon quantification approaches in mangrove restoration projects.

addressed generally by Verra and is not considered in the Climate Action Reserve and Plan Vivo programmes.

An additional challenge for robust quantification of the mitigation impact of Blue Carbon projects is the assessment of autochthonous vs. allochthonous carbon in BCE (see Box 1 below and UBA (2025b) for further details).

Box 1. The relevance of autochthonous vs. allochthonous carbon in Blue Carbon ecosystems.

The uptake of CO_2 in BCE and its direct conversion into biomass or organic matter and storage in the respective BCE directly contributes to active removal of CO_2 from the atmosphere, hence it is relevant in terms of climate change mitigation. This internally produced organic matter is the **"autochthonous" carbon**. However, through the continuous exchange with adjacent terrestrial and marine ecosystems, BCE also receive and store large amounts of externally produced organic matter, the **"allochthonous" carbon**.

In terms of carbon accounting in carbon crediting programmes issuing carbon credits to Blue Carbon projects, **only the autochthonous carbon is climate-active**, i.e. the deposited carbon results from CO_2 uptake and conversion into biomass and is stored for a long time in the project area. In contrast, the allochthonous carbon results from CO_2 uptake somewhere else and its long-term storage would have occurred anyway. The **portion of allochthonous carbon in BCEs varies largely**, but is generally high, **on average ranging between 40-70%** (Williamson et al. 2025). Not accounting for the part of the carbon that is not "climate-active" carbon bears the risk of overestimating the GHG ERRs, hence, over-crediting in such a Blue Carbon project.

A distinction between autochthonous and allochthonous carbon requires sophisticated and reliable methods due to the complex nature of organic matter. Several techniques exist to identify carbon sources with varying degrees of certainty, including elemental composition, stable isotopes, biomarkers, molecular properties, and environmental DNA. However, due to overlapping value ranges and other limitations, these methods do not always yield definitive results. The carbon crediting programmes vary significantly in their approach and requirements for quantification methods for specific carbon pools, addressed in the in the methodological protocols (see Table 2). It appears that the determination of allochthonous carbon for an accurate quantification of the climate-active soil carbon is considered of minor relevance in current carbon crediting programmes. While Verra's VCS approach seems to be most advanced and detailed, its wide spectrum of quantification options also leaves room for large uncertainties in calculation results.

There are also recommendations not to deduct allochthonous carbon (Lovelock et al. 2023; Houston et al. 2024). For instance, the Australian Carbon Credit Unit scheme argues that terrestrial carbon would likely decompose during transit to coastal ecosystems and thus would not be stored without the project, meaning that all soil carbon, including the allochthonous portion, can be considered additional and not counted in national GHG inventories or NDCs (Lovelock et al. 2022; Lovelock et al. 2023).

However, taking a conservative approach to avoid overestimating ERRs and preserving environmental integrity, **all allochthonous carbon should be deducted and the most conservative approach should be chosen** to calculate GHG ERRs from soil carbon accumulation in Blue Carbon projects. Because of the existing limitations and uncertainties not only in carbon accounting in coastal ecosystems, but in all terrestrial and marine ecosystems, the precautionary principle should be followed and allochthonous carbon be quantified and generally deducted. Further information can be found in UBA (2025b).

3.2.3 Addressing non-permanence risks

Another key aspect for high-quality BCPs is the "permanence" of the emission reductions or removals, which is crucial to ensure environmental integrity. In case the preserved or enhanced carbon stock achieved through Blue Carbon projects are released back to the atmosphere at a later point in time, net global emissions will be higher if these credits were used to compensate for emissions. The risk of non-permanence is influenced by three factors, which include **the extent to which carbon reservoirs are susceptible to natural or human-caused reversal risks** like, for example, wildfires, storms, droughts or diseases (unintentional reversals), or mismanagement, or abandoning of the project due to changes in local conditions that make it no longer attractive to keep carbon stored (intentional reversals); **the size and scale of carbon reservoirs**; and **whether and how human-caused drivers of depleting carbon reservoirs are addressed** (see FAO 2024; UBA 2022)**.**

The reversal risk is high for all types of Blue Carbon activities, with specific risks varying depending on the type of biospheric reservoir. In mangrove forests, carbon sequestration may be reversed due to erosion, increased decomposition, or human actions such as deforestation related to conversion to aquaculture and agriculture, and urban development. Seagrass meadows face reversal risks from natural hazards like floods, cyclones, and water quality degradation, as well as human interventions such as coastal construction, siltation, and fishing. Tidal marshes are vulnerable to erosion, invasive species, and environmental pollution, with major human drivers including coastal land-claim, agriculture, the salt industry, and urban sprawl. Coastal squeeze and the loss of low-lying or submerged land or vegetation are common threats across all ecosystems.

The following approaches are available for addressing non-permanence (CCQI 2022; FAO 2024):

- **Assessing and reducing non-permanence risks** by requiring non-permanence risk assessments and excluding mitigation activities with higher risks from eligibility and/or requiring measures to mitigate the risks. Regarding the analysed crediting programmes, Verra's VCS excludes projects with a non-permanence risk rating above 60% unless mitigation measures reduce the risk*, and* provides a software-based tool that allows to conduct a risk analysis. Similarly, the Mexico Forest Protocol adjusts the risk buffer contribution based on risk category scores and project duration, while Plan Vivo applies a fixed 20% buffer and mandates periodic reassessments, though without detailed thresholds.
- **Compensating for reversals:**
  - **Crediting based on monitoring and compensation for reversals**: Monitoring of carbon stocks over long time periods and provisions for cancelling other credits in case a reversal occurs. Key features in the programmes' provisions include for how long monitoring is required and how responsibility for compensating for reversals is assigned. All types of reversals (intentional and unintentional ones) should be compensated for (by project owners and/or pooled buffers). It should also not be allowed to update the baseline after a reversal has occurred. All three carbon crediting programmes make project owners liable for identifying and compensating both, avoidable and unavoidable reversals. Additionally, they have pooled buffer reserves in place which are in principle a suitable instrument to insure projects against reversals, as projects that are implemented in different ecosystems and across different regions contribute to each of the pooled buffers so that reversal risks are diversified across different ecosystems.

- **Crediting based on issuance deductions**: Issuing credits only for a fraction of the mitigation achieved to account for possible future reversals.
- **Temporary crediting:** Issuing temporary carbon credits that expire after a certain time period, which need to be replaced by other credits as they expire (Marland and Marland 2009; Maréchal and Hecq 2006; Marland et al. 2001; Sedjo and Marland 2003). This approach is not applied by any of the crediting programmes analysed.

- **Tonne-year accounting**: Issuing only fractional amounts of credits for each year that carbon remains stored (FAO 2024). This approach is not applied by any of the crediting programmes analysed.

In general, all three programmes require some sort of risk assessment to reduce the risk of non-permanence, but the adequacy and transparency of the measures vary.[10] Most Blue Carbon projects have a duration of 20-40 years and therefore do not qualify for permanent removals, which would require maintaining carbon stocks in these ecosystems for 100 years or more. The approach of using a pooled buffer depends on whether it is sufficiently capitalised, as undercapitalised buffers may threaten the environmental integrity of a crediting programme since they may not be able to compensate for potential future reversals. Also, none of the crediting programmes seems to have liability mechanisms in place in case the programme ceased its operations. These challenges can undermine the integrity of Blue Carbon credits, particularly if these were used for offsetting claims. There is a need for stronger liability mechanisms, and continuous monitoring to ensure that claimed mitigation benefits are not lost over time. Yet, reversal risks can never be fully avoided for Blue Carbon projects.

3.2.4 Environmental and social impacts

Carbon crediting projects have impacts that go beyond GHG emissions reductions and removals. There might be impacts on social and environmental goods which influence the outcome and perception of such projects and projects might contribute more broadly to sustainable development, not only through emissions reductions. Hence, the robustness of the environmental and social safeguards that developers must apply to prevent negative impacts and the degree to which projects promote and assess benefits beyond carbon crediting and contribute to sustainable development, must be distinguished.

All major carbon crediting programmes include environmental and social safeguards to prevent harm and ensure alignment with development goals. These safeguards include the possibility for global as well as local and affected stakeholders to voice concerns and demand fair treatment and, when appropriate, redress or compensation and apply to all project types, including Blue Carbon, and compliance lies with project owners. While programmes like CAR and Plan Vivo include detailed, locally adapted FPIC (free, prior and informed consent) procedures, enforcement is key. Research has found gaps in safeguard clarity, though many programmes have since improved their provisions in line with IC-VCM principles.

Blue Carbon projects bear more risks to disturb social cohesion in local communities than to negatively impact the environment. In terrestrial REDD projects changes in land use practices have led to local disputes and in some cases researchers have reported human rights violations in these projects (Berkeley Carbon Trading Project 2023). While no major conflicts have been reported so far, experiences from terrestrial REDD show that strong, enforced social safeguards and inclusive community engagement remain essential to prevent negative impacts. A key

[10] A detailed analysis of the approaches to address non-permanence of the three analysed carbon crediting programmes can be found in Table 24 of ZMT; Oeko-Institut (2025).

safeguard in this context are provisions requiring project developers to obtain free, prior, and informed consent from local communities for the project activities. All three carbon crediting programmes have respective provisions in place. Provisions further include requirements on the minimum information that project developers must disclose before establishing such an agreement. Overall safeguards strongly depend on how the provisions of the carbon crediting programme are enforced on the ground locally in the projects.

The overall sustainable development impacts of projects can still vary considerably. Projects in the VCM may catalyse significant positive social and economic co-benefits that go beyond GHG emission reductions, but sustainable development impacts depend strongly on the individual project and local context (e.g. Wissner et al. (2022), Hernández-Orozco et al. (2022), Nilsson et al. (2016)). While projects might claim various co-benefits, these need to be assessed, verified and reported in a transparent manner. Clear programme provisions to promote, assess and monitor sustainable development impacts can improve the overall impact of carbon credit projects, and make them more transparent and credible.

The carbon crediting programmes considered in this study vary in how they promote and monitor these impacts: the most recent standard version in the Verra VCS programme requires explicit demonstration of SDG contributions; CAR requires project developers to monitor a project's contributions using an SDG reporting tool; Plan Vivo focuses on community and livelihood benefits. Blue Carbon projects often provide co-benefits like ecosystem restoration, coastal protection, biodiversity support, and improved livelihoods. For example, Colombia's Vida Manglar project reports gains in biodiversity and local governance. Kenya's Mikoko Pamoja highlights income generation and community enterprise. Pakistan's large-scale Delta Blue Carbon project includes job creation, women's empowerment, and access to healthcare and education. These cases highlight the potential of Blue Carbon projects to deliver meaningful local and environmental benefits when properly designed and implemented.

3.2.5 Preventing double-counting

Double counting occurs if the same mitigation outcome is counted more than once towards the achievement of a mitigation goal (NewClimate Institute; Schneider 2020; Schneider and La Hoz Theuer 2019). It can lead to higher aggregate emissions in the atmosphere and thus undermine the environmental integrity of a crediting mechanism (Schneider et al. 2015; OECD 2013; NewClimate Institute; Schneider 2020; UBA 2022; CCQI 2022; Oeko-Institut; Ecologic Institut; Universität Gießen 2023). There are three types of double counting:

- Double issuance of credits for the same mitigation outcomes, e.g., by two different crediting programmes;
- Double use of credits that are cancelled twice in a programme's registry;
- Double claiming by two different actors who use the same credit to achieve different climate targets.

For Blue Carbon projects, there is a potential risk of **double issuance due to indirect overlaps between projects**, e.g., when a project takes place in the same geographic area as one reducing firewood consumption and both projects might claim the same removals or emission reductions. This risk could be addressed during the project appraisal process by implementing systematic checks whether the project area overlaps with that of other carbon market projects.

The risk of **double claiming** is also relevant, as a removal can be claimed by the host country for its NDC and by another country or entity buying the credit. To avoid this, mitigation activities need to be **authorised under Article 6** of the Paris Agreement. The host country needs to make '**corresponding adjustments**' to their reported emissions, adjusting them upwards by the number of credits sold, and the buyer must reduce its balance accordingly (CCQI 2022).

Carbon crediting mechanisms and participating countries need rules to track authorised emission reductions and removals. The purpose for which credits are used must be clearly and transparently documented. If used towards an NDC, programmes should require documentation of the authorisation and indicate it in the registry. Similarly, registries should tag credits authorised for the VCM (CCQI 2022). While some programmes like CAR and VCS have introduced Article 6 provisions requiring host country authorisation and registry transparency to prevent double claiming, others like Plan Vivo lack such safeguards.

4 Financing Blue Carbon Projects[11]

4.1 Overview of Financing Approaches

Beyond carbon credits – the main focus of this research project – there are various other financing approaches and funding sources, which governments can deploy to support coastal ecosystem conservation and restoration. It includes more traditional sources such as domestic public finance as well as new ones which emerged only recently, such as blue bonds. Based on Oeko-Institut; IfW (2025), the following section briefly outlines nine different funding sources, including carbon credits, as a basis to compare the risks associated with the use of carbon credits to risks associated with other financing approaches.

Carbon credits represent standardised units of one tonne of CO_2 equivalent reduced or removed. Regarding Blue Carbon projects, carbon credits are primarily used voluntarily by companies, organizations, governments, and individuals. This report focuses only on funding from voluntary climate action, while the suitability of BC carbon credits used for NDC achievement is not analysed in this report. One relevant use case for carbon credits is **offsetting residual emissions as part of voluntary climate neutrality commitments** by various actors on the level of an individual organisation or product, via the voluntary carbon market. It is estimated that capital expenditure for projects in the VCM amounted to over USD 40 billion between 2013 and 2023, with about 50% occurring between 2021 and 2023 (Lambert and Turner 2024). Carbon credits and their use for offsetting claims are subject to intensive public scrutiny. This is because if these claims are backed by carbon credits that have a high risk to not represent a tonne of removed or reduced CO_2, it will lead to higher overall atmospheric emission levels and thus undermine the environmental integrity of carbon market mechanisms (see section 3.2 and Schneider and La Hoz Theuer 2019). Next to scientific scrutiny, offsetting claims also increasingly became subject to lawsuits revolving around the question whether their use for climate neutrality claims on product level misleads consumers. Using carbon credits for offsetting claims is therefore increasingly associated with reputational risks.

While offsetting claims have been the predominant use case in the past decade**, carbon credits can also be used in the context of contribution claims**. In this form of claims, organisations communicate that they contribute to climate mitigation without claiming that the organisation itself or one of its products is “climate neutral”. Different approaches that organisations can use to determine the size of their contribution for any given year include the tonne-for-tonne approach, where an organisation links the size of its climate contribution to the size of its remaining emissions in that year; the money-for-tonne approach, where an internal carbon price is set and multiplied with its remaining emissions to determine the size of its contribution; and the money-for-money approach, where a financial metric such as a percentage of its revenue is used (see also Oeko-Institut e.V forthcoming). Major certifiers like SouthPole, MyClimate, and ClimatePartner have replaced “carbon-neutral” product labels with contribution claim models (myclimate 2023; South Pole Group 2023; ClimatePartner 2024). Organizations such as Gold Standard, WWF, and Carbon Market Watch have also supported this shift (Schallert et al. 2020; Gold Standard 2024; Carbon Market Watch 2020; Climate Action Network 2021). This might suggest that the VCM as a whole may move towards this alternative approach to offsetting in the future.

Organisations can also use modalities other than carbon credits for making their climate contributions. This applies mostly to organisations using the money-for-tonne or money-for-

[11] Please refer to Oeko-Institut; IfW (2025) which this chapter is based on for further details.

money approach to determine the size of their contribution and do not necessarily need the detailed monitoring of the GHG impact of the funded activities, which currently only carbon credits provide. These approaches therefore offer more flexibility on how funding is channelled. While organisations may make climate contributions as individual organisation, they can also pool their individual contributions into funding vehicles such as a dedicated fund to increase the impact of contributions, like the Milkywire Climate Transformation Fund which pools climate contributions by Swedish fintech company Klarna and other companies (Milkywire 2024).

Biodiversity credits aim at commodifying biodiversity for financial mechanisms that provide funding for measured, evidence-based, *positive* biodiversity outcomes that would not have occurred without the incentive provided by these credits. Conceptually, biodiversity credits are related to, but distinct from biodiversity *offsets*, which are a well-established regulatory instrument available to companies under national environmental legislation in many countries to compensate for a loss in biodiversity they cause elsewhere. Unlike biodiversity offsets, which are used to compensate for biodiversity loss under legal frameworks, biodiversity credits support broader conservation efforts and are often used for corporate branding or ESG benefits. However, many existing credit schemes face challenges, such as unclear baselines, lack of third-party verification, and difficulty quantifying biodiversity outcomes, especially in marine ecosystems (see Wunder et al. 2024). These limitations currently make most biodiversity credits unsuitable for compliance-based offsetting.

Official Development Assistance (ODA) flows that target Blue Carbon projects are comparatively small. The exact volume of these flows is difficult to determine because available ODA statistics are not sufficiently granular to quantify flows that target coastal ecosystem conservation and restoration. While some aid flows support ocean-related objectives, most focus on areas like maritime transport or pollution reduction. Only a small portion is likely directed toward the conservation and restoration of carbon-rich coastal ecosystems, highlighting a gap between climate and biodiversity ambitions and funding priorities (OECD 2024). Moreover, there is a comprehensive network of **multilateral organisations** that support projects related to marine protection, including, among others, the Global Environment Facility (GEF), the Global Biodiversity Framework Fund (GBFF), as well as the Multilateral Development Banks (MDBs) and further multilateral funds, like the Green Climate Fund (GCF), the Adaptation Fund, the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF). While funds often support similar activities, such as mangrove and seagrass restoration, their motivations differ. Each fund is guided by a distinct mandate, shaping its rationale for investing in these ecosystems. In general, multilateral funds are well positioned to support Blue Carbon projects as they have several years of experience with mangrove and seagrass conservation and restoration projects. While most funds do not yet account for CO_2e mitigation from mangrove projects, they do so for other project types. Adapting existing results frameworks to include Blue Carbon would be possible with robust and cost-effective methodologies. A recent GEF-funded project marks the first multilateral effort to develop such approaches for mangrove forests, seagrass meadows, and saltmarshes (UNEP 2013).

Governments play a central role in financing the conservation and restoration of coastal ecosystems through **domestic public finance within their national budgets**. Allocating funds for measures such as mangrove and seagrass protection and replanting can be motivated by different factors, such as coastal protection or benefits for the fisheries industry. Public finance typically funds marine protected areas (MPAs) and integrated coastal zone plans, sometimes supported by environmental taxes, as seen in Fiji and the Seychelles specifically in the tourism sector (Fezzi et al. 2023). However, limited budgets and competing priorities often restrict funding, especially in politically unstable regions.

Philanthropic grants and donations are considered as a significant source of funding for mangrove restoration projects. By supporting community-based models and integrating scientific approaches, philanthropy can play a transformative role in advancing Blue Carbon conservation globally (World Bank 2023). Motivations range from corporate social responsibility (CSR) to global conservation goals (Vanderklift et al. 2019), but long-term support is often uncertain. Funding typically comes from Global North donors and may assist voluntary carbon market entry or innovative models like Project Finance for Permanence (PFP), which blends private, public, and philanthropic funds for long-term sustainability. PES schemes, supported by philanthropy, have shown success in countries like Bangladesh.

Tourism-related fees are an important tool to fund ecosystem preservation, also in mangrove and kelp forests, usually as part of a marine protected area (MPA). The fees charged include simple entrance fees as well as fees for activities such as diving, scientific work or, if permitted, fishing, and are often seen as one way to address the issue that many MPAs lack the financial means for adequate management and enforcement of conservation regulations. Still, raising funds through visitor fees can face challenges related to logistics, political stability, natural disasters or social acceptance. In most MPAs, visitor fees will not be able to raise enough funds to cover the entire operating cost, as the willingness to pay (WTP) is generally too low. They can contribute, however, to diversifying income streams and reduce the management's reliance on domestic and international donors.

Debt-for-nature swaps (DNSs) are financial mechanisms in which creditors, often of developed countries, agree to cancel external debts in return for the debtor commitment to biodiversity conservation or economic decarbonization. While DNSs have generated over USD 1.2 billion for conservation and supported major initiatives in countries like Belize and Ecuador, their overall scale remains limited. Risks include corruption and political instability, and DNSs alone cannot meet the vast financing needs for climate action.

Based on the concept of green bonds, **blue bonds** serve as a financial instrument to generate funds for investments in the blue economy in the broadest sense, also including marine preservation projects and therefore BC ecosystem projects. Like normal bonds, they are debt instruments issued by governments or other actors, with the difference that the money raised must be invested in sustainable marine and maritime projects. The debt is repaid with interest, meaning that the investor expects a financial return, and due to the nature of the projects invested in, an environmental return can also be expected. Since the first sovereign blue bond by Seychelles in 2018, the market has grown to a cumulative USD 7.2 billion by 2023 (BNN Bloomberg 2024), which is still small compared to green bonds. Most blue bonds have been issued in United States Dollars with the Euro currently being underrepresented in the market. While Blue Carbon is an eligible investment category, carbon sequestration remains a niche use; most funds go toward waste management, fisheries, and tourism. As a relatively new concept, blue bonds face several challenges, including eligibility requirement, which are not yet standardized and increase the potential for "blue washing", and the high complexity process of issuing process. Still, if their green counterpart is any indicator, they can be expected to play a major role in the future of the blue economy, especially in developing countries.

4.2 Advantages and Disadvantages of Carbon Credits compared to other Financing Instruments

Deciding whether to use carbon credits as a funding source for Blue Carbon activities will also depend on the availability of alternatives – i.e. the possibility to scale up flows from other sources. This section summarises advantages and disadvantages of carbon credits compared to other funding instruments with regard to six aspects which play a role in determining the suitability of instruments to raise funding for coastal ecosystem conservation and restoration activities.

- **Maturity:** On a global level, carbon credits are a mature funding instrument. There is now more than 20 years of experience with the instrument and carbon crediting projects have been implemented in almost any country of the world. The complexity of the instrument and its associated risks for the atmosphere and environment in the context of offsetting are well known as are approaches which can avoid them or minimize and manage their effects where full avoidance is not possible. Further, there is a large international network of specialists and firms that can reliably provide the different services required for carbon crediting such as methodology and project development as well as validation and verification of project results. While Blue Carbon projects are a comparatively new project type, much of the accumulated expertise can be used for developing and verifying these projects. Here carbon credits have a comparative advantage when compared to biodiversity credits which are at the early stage of their development and some conceptual and operational details not yet being defined. Carbon credits are likely also more mature than debt-for-nature swaps and blue bonds. Domestic public finance, bilateral and multilateral development cooperation, philanthropic grants, and contributions as well as tourism entry and activity fees on the other hand are likely more mature than carbon credits, especially at the local levels. There is ample experience in using these sources for coastal ecosystem protection and restoration.
- **Scalability of financial flows:** Carbon credits, regardless of whether they are used for voluntary offsetting or contribution claims mobilise funding from a different pool of resources than the traditional funding sources deployed for coastal ecosystem protection. Scaling financial flows through voluntary carbon markets is not restricted by the same barriers that prevent scaling of domestic public finance or bilateral and multilateral development cooperation, for which scalability hinges on fiscal space of governments. Further, carbon credits do not require payback or interest payments, which restricts the scalability of sources such as blue bonds or debt-for-nature swaps for countries with limited fiscal space and lack of access to capital markets.
- **Predictability and stability of flows:** The carbon credit market continues to be fragmented and different prices apply for different market segments and project types. Furthermore, carbon prices for the same project type frequently fluctuate between years. This also applies to carbon credits from Blue Carbon projects. The average price at which Blue Carbon credits were transacted in 2024, for example increased by about 257% compared to 2023 levels (Ecosystem Marketplace 2025). Historically, price instability has been a significant concern for projects funded by carbon credits and some projects had to be rescued with public funding after the collapse of the CDM market. Continued price volatility makes it difficult for projects to estimate the volume of future revenues that they will be able to receive through carbon credits. Other funding sources might currently perform better in this aspect, although all face some form of predictability issues but to a lesser degree. If the voluntary carbon market reached a more concentrated state with high price stability, carbon credits could potentially be a very stable source of income. This is related to the long-term investment horizon of carbon credits. Current projects have crediting periods between 20-60 years, which is much longer than for the other funding sources assessed in this report. Development cooperation and philanthropic grants often follow project cycles of 5-10 years. Also, current blue bonds and dept swaps have investment horizons of about 20 years. Budgetary contributions are even more short-term as in most cases contributions must be negotiated on an annual basis. However, payments for carbon credits are only provided ex

post upon verification of achieved mitigation results, while most funding sources provide support on an ex-ante basis, providing security and upfront funding to implementing actors with potentially limited budgets.

- **Carbon accounting readiness:** Carbon credits are the only funding source which currently requires project owners to perform high-resolution measurements of the mitigation effect of funded activities. The greenhouse gas emission monitoring frameworks built for carbon crediting projects surpass those of projects funded through any of the other sources in terms of comprehensiveness and granularity. These projects therefore also make an important contribution to advance scientific understanding of the carbon fluxes in coastal ecosystems. At the same time, experience with quantifying mitigation impacts of activities aiming to conserve and restore terrestrial ecosystems has shown that current ecosystem-related measurement frameworks built for carbon credits often return estimates with very high uncertainty. This reflects that it is very difficult to measure the effect of project activities on some carbon pools such as soil organic carbon. Other sources such as development cooperation and philanthropic grants feature indicators to track emission reductions and removals in their result management frameworks. Monitoring is however much less granular and relies on more basic approaches. It is most likely that other funding sources have not adopted the measurement infrastructure built for carbon credits because it is costly and creates additional burden for project development and implementation. In principle, any funder will be interested in the impact of funded activities on GHG metrics even though it might not be a primary motivation to start a restoration activity. It might be worthwhile to explore whether approaches used in carbon crediting could be adopted in the context of other funding sources. This would however require a careful cost-benefit analysis considering the transaction costs involved.

- **Transaction costs:** Because of their comprehensive and granular GHG measurement framework, carbon credits likely have higher transaction costs than some of the other funding sources, which rely on more basic approaches to measure GHG impacts of funded activities or do not measure them at all. Overall, there is however little information available on monitoring and certification costs for carbon crediting projects that target the conservation and restoration of ecosystems. It is therefore not possible to make estimates about the extent of average transaction costs of Blue Carbon projects vis-à-vis other funding sources. Further research in this area is recommended. Among the other funding sources, debt for climate swaps likely have the highest transaction costs as their complexity requires involvement of many actors as well as engagement of highly specialised advisors.

- **Integrity risks:** Integrity risks are material for carbon credits from Blue Carbon projects as our analysis summarised in section 3.2 of this report has shown. The project sample also shows that there is evidence that risks implied in the design of crediting methodologies also materialise in concrete projects on the ground. Among the other funding sources outlined in section 4.1, only biodiversity credits have similar environmental integrity risks, albeit risks may not be related to atmospheric emission levels but their effect on the overall extent of global biodiversity. Yet, other sources may equally have risks to result in problematic outcomes for the environment. For example, relying on revenues from tourism entry and activity fees might create incentives to allow more visitors into an ecosystem than is ecologically healthy. Blue bonds can lead to funding harmful activities if there is no clear taxonomy that defines what activities have positive impacts for the oceans in a scientifically robust manner. Research found for example that in existing blue bonds some impact metrics are not in line with well-established norms such as the two-degree climate scenario, which raises a discussion over whether these bonds are sustainable (Bosmans and Mariz 2023).

5 Carbon Reporting and Accounting for GHG Emissions and Removals in Blue Carbon Ecosystem[12]

5.1 Overview of Relevant IPCC Reporting Guidelines and Their Application

National GHG inventories are the primary tool for monitoring and reporting emissions and removals from sectors including LULUCF. Under the Paris Agreement, all will submit biennial transparency reports (BTRs) under the **e**nhanced transparency framework (ETF)**,** including national GHG inventories and applying IPCC Guidelines for National Greenhouse Gas Inventories. These guidelines already cover management activities in mangrove forests within the LULUCF sector. Guidelines on how to estimate GHG emissions for activities in saltmarshes and seagrass meadows are part of the 2013 Wetland Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2014), which provides information on accounting for uncertainties and data gaps in the estimation of carbon stocks. Currently, there is no obligation to use the methods introduced in the 2013 Wetland Supplement, measures relating to BCEs are only included in national GHG inventories on a voluntary basis. If countries decide to report activities in BCEs, they must clearly define the extent and location of their activities in these ecosystems to meet their international reporting obligations in the ocean. The reporting obligations extend, according to UNCLOS, to the EEZ and to certain activities on the continental shelf (if claimed), where emissions and removals must be stated separately.

Emissions and removals resulting from anthropogenic activities in mangrove forests, tidal marshes, and seagrass meadows are reported under the sector of land use, land use change and forestry (LULUCF). Only emissions and removals from managed lands and changes in land use need to be reported, total carbon stocks are not reported in the national GHG inventories.

The 2013 Wetland Supplement uses a tiered approach to estimate GHG emissions from wetlands, depending on the level of available data and the level of uncertainty associated with the estimates. The supplement offers methodological guidelines for practices relevant for BC projects and includes Tier 1 default emission factors for reporting of non-CO_2 emissions and CO_2 emissions resulting from changes in different carbon pools of mangrove forests, seagrass meadows and tidal marshes (see Table 4). In general, the IPCC recommends using Tier 2 or Tier 3 assessments when possible, due to the high level of uncertainty of Tier 1 methods (IPCC 2014). The IPCC guidelines cover BCE relevant activities like, for example, emissions resulting from drainage, which is one of the major causes for degradation in coastal ecosystems. Guidance in this regard is only available for mangrove forests and tidal marshes (Table 4). Restoration activities such as rewetting and revegetation are also described, which are important potential BC measures (Table 4). The most recent update to the 2013 Wetlands Supplement is the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2019b), which provides guidance for assessing changes in the soil carbon pool, particularly important in cases in which coastal wetland areas are converted to agricultural lands or aquaculture.

Fehler! Verweisquelle konnte nicht gefunden werden. Guidelines for mangrove forest management are already available under the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). If mangrove forests fall under the countries forest definition, they are reported under the land use category “Forest land,” otherwise they can be included under “Wetlands”. Tier 1 default values are not available for all carbon pools and if national data is not available, they do not have to be reported. Hence, only using Tier 1 default data for national

[12] Please refer to Oeko-Institut; ZMT (2024); UBA (2025a); UBA (2025b); UBA (2025a) which this chapter is based on for further details.

reporting can lead to high uncertainties in the emission and removal estimates. Additionally, the Tier 1 emission factors may not be based on statistically sound data. For example, Tier 1 emission factors for seagrasses are derived from only six sampling sites (Needelman et al. 2018). However, providing these default data also removes significant barriers to including coastal wetlands in national GHG inventories and can help to increase efforts to improve data and knowledge on the state of coastal wetlands (Green et al. 2021). Further details on IPCC reporting methodologies are summarised in Oeko-Institut; ZMT (2024).

Table 4: Activities for which Tier 1 emission factors are available for reporting of non-CO_2 emissions and CO_2 emissions resulting from changes in different carbon pools of mangrove forests (M), seagrass meadows (SM) and tidal marshes (TM)

Activity	Above & below ground biomass	Dead organic matter	Soil carbon (mineral/organic soil)	Non-CO_2
Forest management practices	M	M (if land-use change occurs)	M	-
Extraction, for example for aquaculture or saltponds	M	M	M, SM, TM	-
Aquaculture use	-	-	-	M, SM, TM (N_2O)
Drainage	M	M	M, TM	-
Rewetting, revegetation and creation	M	-	M, SM, TM	M, TM (CH_4)

Data sources: IPCC 2014, Green et al. 2021.

As of October 2023, only seven out of 36 countries with coastal wetland areas include at least one BCE in their national GHG inventory. Mangrove forests are the most frequently reported, followed by tidal marshes (Table 5, UBA 2025a). The most advanced reporting of activities in BCE is provided by Australia and the USA, which include emissions and removals from tidal marshes and mangrove forests in their inventory. They report on non-CO_2 and CO_2 emissions from activities like the destruction of seagrass meadows and CO_2 removals from restoration/regeneration activities like arising in these BCE (Oeko-Institut; ZMT 2024). Australia developed and applied a specific Tier 3 model that includes a wetland module to account for carbon stock changes in coastal wetlands Full Carbon Accounting Model (FullCAM)) (Australian Government 2023). The USA applies country specific emission factors (Tier 2 and 3) as well as default values (Tier 1) for “Vegetated Coastal Wetland”, which include mangrove forests as well as tidal marshes EPA 2023 (EPA 2023, p. 6-103ff.).

Table 5: Overview of countries including coastal wetlands in their national GHG inventories

Country	Includes only an overall reference to coastal ecosystems in NIR	Includes mangrove forests in NIR	Includes seagrass meadows in NIR	Includes saltmarshes in NIR
Australia	-	X	X	-
Cyprus	X (saltmarshes)	-	-	-

Country	Includes only an overall reference to coastal ecosystems in NIR	Includes mangrove forests in NIR	Includes seagrass meadows in NIR	Includes saltmarshes in NIR
France	-	X	-	X
Japan	-	X	-	-
Malta	-	-	-	X
New Zealand	-	X	-	-
United Kingdom	-	X	-	-
USA	-	X	Announced for 2024	X
Iceland	X (tidal marshes)	-	-	-

Sources: Own compilation based on sources published in UBA (2025a).

5.2 Opportunities for Expanding Blue Carbon Reporting and Accounting Frameworks

The current reporting on BCE in national GHG inventories is insufficient for a reliable assessment of the GHG emissions and removals arising from BCE (see section 5.1). However, including BCE in national GHG inventories offers the opportunity to gain an overview of emissions from BCE to develop and implement appropriate measures to reduce emissions. To strengthen the integration of GHG reporting of BCE targeted improvements are necessary. These include (Oeko-Institut; ZMT 2024):

- **Data collection** on the extent and changes of BCE, using tools like, for example, remote sensing.
- **Refinement of the emission factor data base**, especially the IPCC Emission Factor Database, by incorporating data on GHG fluxes linked to varying intensities of human activities (e.g., vegetation clearing, drainage, restoration).
- **Improved carbon stock assessments**, particularly at soil depths beyond 1 meter, and better measurement of carbon accumulation rates.
- **Further research into allochthonous carbon inputs** from marine and terrestrial sources to ensure accurate and consistent reporting.
- **Sufficient finance to support long-term research, monitoring, and data infrastructure** for GHG fluxes in BCE.

Additionally, according to a recent assessment of GHG reporting of Blue Carbon among Member States (MS) of the European Union (Remeta et al. 2025), the MS could specifically indicate whether they include coastal wetlands under the category “wetlands” in their national GHG inventory. Also, coastal wetlands could be included as a subcategory in the common reporting table.

6 Conclusion and recommendations

Coastal ecosystems hold carbon stocks mainly in sediments of mangrove forests, seagrass meadows and tidal marshes, which are also called Blue Carbon Ecosystems (BCE). Although some of them benefit from some degree of protection, global carbon stocks in these ecosystems have declined over recent decades. These ecosystems are endangered by, for example, the spread of aquaculture in coastal regions, bottom trawling or pollution, which leads to GHG release due to degradation or even total destruction of BCE. For mangrove forests, the primary drivers of this loss include land-use pressures through rice cultivation and aquaculture. Illegal deforestation by local actors who use mangrove habitat for fuelwood collection and subsistence farming only play a minor role.

Measures to protect and restore BCEs have been proven to reduce GHG emissions even though globally, the potential contribution of the three BCEs to achieve additional significant carbon sequestration is limited. Nevertheless, in some countries that have high shares of coastal ecosystems, the BCEs can contribute to mitigation and climate adaptation efforts. At the same time, actions to protect and restore BCEs have numerous sustainable development co-benefits, especially for protecting biodiversity and adaptation to impacts of climate change, such as flooding.

The IPCC guidelines for GHG monitoring lay out methodological approaches for including mangrove forests, seagrass meadows and tidal marshes in national GHG inventory reports. There are methods and emission factors available for several activities in these ecosystems. Yet, the temporal and spatial complexity of coastal ecosystems, coupled with the limited availability of data on carbon fluxes in these environments, leads to significant uncertainties in estimating GHG fluxes and carbon stocks. This is particularly relevant when default emission factors are used. Due to these methodological, technical and financial obstacles, the visibility of BCEs in national GHG emissions reporting is currently limited, as only a few countries with coastal ecosystems are able to report their emissions and removals. Still, pursuing efforts to include coastal ecosystems in national GHG inventories can shed light on the GHG emissions within these ecosystems, thus promoting initiatives to reduce these emissions through restoration and discouraging harmful activities.

For decades, governments around the world have been funding measures to conserve and restore coastal ecosystems. The reasons why governments fund these measures are manifold. Coastal ecosystems have significant ecological importance, providing vital habitats for numerous species. They also offer essential services to key economic sectors such as fisheries and tourism, and they enhance the resilience of coastal zones against erosion and sea-level rise. Due to the large network of interested stakeholders, governments have access to a diversified portfolio of funding sources to support coastal ecosystem conservation and restoration. While domestic contributions have been the main source for such efforts so far, governments were also able to rely on ODA, philanthropic grants, and revenues from tourism entry fees. These funding sources are likely more mature than carbon credits, especially at local level. Alternative funding sources include debt-for-nature swaps, blue bonds and biodiversity credits, which are becoming increasingly popular. However, challenges regarding the quantification of biodiversity benefits and the lack of standards pose obstacles to their implementation on a larger scale.

Despite the large network of supporters, funding has often been insufficient to achieve national ambitions of increasing resiliency and preserving critical ecosystems. The ability to monetize the carbon storage function of BCE via carbon credits has therefore gained more attention of governments and of many other stakeholders alike. As such, they offer a potential source of funding for activities aimed at restoring degraded coastal habitats or safeguarding existing ones from further degradation.

However, unlike other forms of financing, such as philanthropic contributions or development assistance, the use of carbon credits as a funding mechanism introduces a critical trade-off. If used for achieving climate change mitigation targets, each credit issued permits a corresponding tonne of CO_2 emissions elsewhere, making the environmental integrity of the credit essential. If credits are issued without ensuring additionality, permanence, and conservative carbon accounting, the result may be a net increase in global emissions. In effect, society could be subsidising new coastal ecosystem protection and restoration efforts with higher levels of atmospheric CO_2 – a counterproductive outcome. This underscores the need for stringent safeguards, robust methodologies, and strong oversight mechanisms to ensure that carbon crediting genuinely supports climate mitigation rather than undermining it.

From an analysis of seven selected Blue Carbon projects on the voluntary carbon market – all of which, besides one seagrass restoration project, were either mangrove conservation or restoration activities - we conclude that integrity risks are material when using carbon credits as a funding mechanism for new measures to conserve and restore coastal ecosystems. This is due to risks associated with key aspects of carbon crediting:

- **Additionality**: All of the assessed projects implied risks, that the activities were not additional, i.e. that they would have been carried out without the incentive of the funding provided by the crediting mechanisms. Firstly, it was uncertain whether revenues from carbon credits were the only available funding source. Secondly, in all cases, project developers submitted their project design documents to the respective carbon crediting programme only after the replanting or conservation activities had already begun. The assessment also found an overlap between project sites and protected areas, which can be associated with non-additionality risks, as certain activities assumed to occur in the baseline scenario – such as mangrove logging—are already prohibited under protected area regulations.[13] Overall, and despite these concerns, there is no evidence from the project sample to suggest that non-additionality risks for Blue Carbon projects are more pronounced than for other types of projects funded through carbon credits.

- **Quantification:** Quantifying carbon benefits in coastal ecosystems is highly complex, and the results are inherently associated with uncertainties that can result in over-crediting. Coastal ecosystems exhibit high spatial and temporal variability in carbon dynamics, making it challenging to develop standardized measurement approaches for carbon quantification methodologies. This uncertainty can lead to over- or underestimation of achieved mitigation impacts. Potentially substantial overestimating risks are associated with the approaches to estimating baseline deforestation rates in the project subtype of mangrove *conservation* projects. Additionally, measuring the effect of project activities on changes in carbon pools occurring between baseline and project scenario is associated with uncertainty. The lack of long-term data on carbon fluxes, especially in restored ecosystems and for non-mangrove habitats like seagrass meadows and saltmarshes, makes the estimation of these changes challenging. For biomass carbon accounting, the main uncertainties result from the selection of appropriate allometric equations, the number of sample trees used to construct these equations, as well as location and placement of sample plot design for ex-post measurements of removals. Carbon estimates in all sample projects are affected by these uncertainties.

[13] Yet, it is important to note that this finding is based on a small sample of early-mover projects, and future projects may shift this trend. Project developers may also have legitimate reasons for focusing on protected areas, as these locations often present fewer risks of conflict with local communities, given that land-use restrictions are already in place and do not need to be newly introduced.

Whether these more likely lead to over- or underestimation in the project sample was inconclusive. Lastly, challenges of monitoring organic soils, which are by far the largest carbon pool of BCEs, imply uncertainties that can result in very high over-crediting risks due to the importance of the soil carbon stock for carbon accounting. Methodologies account for these uncertainties in different ways. In one project we found that the quantification methodologies used likely result in notable underestimation of the project's climate impact. Yet, despite these challenges, design choices are available which very likely lead to conservative estimates of carbon removals in mangrove restoration projects.

- **Non-permanence:** Non-permanence is a further critical concern in Blue Carbon projects. Factors such as extreme weather events, sea level rise, erosion, pollution, and land-use pressures pose ongoing risks of carbon reversals—that is, the release of previously sequestered carbon back into the atmosphere. While carbon crediting programmes require buffer reserves or risk discounting to account for such uncertainties, none of them provide guarantees that the achieved mitigation impacts endure for 100 years or more. These challenges can undermine the integrity of Blue Carbon credits, particularly if these were used for offsetting claims. There is a need for stronger liability mechanisms, and continuous monitoring to ensure that claimed mitigation benefits are not lost over time. Yet, reversal risks can never be fully avoided for Blue Carbon projects. This is a finding that applies not only to Blue Carbon projects, but to all projects that monetize the carbon storage function from ecosystems.
- **Safeguards, benefit-sharing and contribution to SDG goals:** Coastal ecosystems are rich in biodiversity as well as highly vulnerable to environmental stressors. Further, about 15% of the global population live within 10 kilometres of the coastline. Often this includes local communities which depend on coastal ecosystems for livelihoods and subsistence. Like any other project activity in these ecosystems, Blue Carbon projects should not negatively affect their environment or the local communities they operate in. Stringent environmental and social safeguards (E&S safeguards) are a key instrument to ensure that projects follow inclusive design processes and include effective environmental management plans which avoid, minimize and compensate for any negative impacts. All carbon crediting programmes under which the sample projects are registered have E&S safeguards. To date there are no known reports of Blue Carbon projects being involved in negatively impacting the environment or lead to conflict over land use. This finding is, however, based on a very small number of projects, which all take place in already protected areas with existing protection regimes which might offer less potential for conflict.
- **Double counting:** Clear guidance is needed on the interaction between voluntary carbon credits and national climate targets under the Paris Agreement, particularly in relation to Article 6 and the risks of double counting. Without such alignment, there is a danger that Blue Carbon credits could undermine rather than complement national mitigation efforts.

In summary, carbon credits are one among several funding sources available to fund BCE conservation and restoration measures. An advantage of carbon credits is that they mobilise resources from a different funding base than traditional sources, as buyers on voluntary carbon markets are mainly private sector actors. They further do not involve repayments and interest payments, which make them attractive for governments that have limited fiscal space and lack access to capital markets, both needed for deploying other innovative sources such as blue bonds and debt-for-nature swaps.

A major disadvantage of using carbon credits are the material environmental integrity risks that apply if these credits are used for offsetting. They might lead – if not properly addressed – to higher overall atmospheric emission levels. Robust quantification poses a particular challenge for crediting Blue Carbon activities because quantifying carbon benefits in costal ecosystems is subject to various uncertainties, e.g. due to a lack of long-term data on carbon fluxes and of standardised allometric equations for biomass accounting. The current very low market share of Blue Carbon projects in the voluntary carbon market compared to other project types reflects the challenges to quantify the mitigation impact of these projects: transactions comprise less than one percent of overall VCM transactions (ZMT; Oeko-Institut 2025). The sample projects do highlight the availability of design choices which very likely lead to conservative estimates of carbon removals in mangrove restoration projects though.

Yet, even if projects use design choices which approach quantification conservatively, certain integrity risks such as the non-permanence risks of avoided emissions and removals remain. Here, stronger liability mechanisms and continuous monitoring are crucial. Alternatively, credits from Blue Carbon projects could be issued as temporary credits with a limited validity, accompanied by requirements from the crediting programmes to replace these credits with permanent mitigation activities upon their expiry. Again, here more dialogue between project developers, carbon crediting programmes and interested buyers of Blue Carbon credits could be useful. In a market that moves towards credits which provide more reassurance of environmental integrity, inability to demonstrate sufficient arrangements to demonstrate non-permanence might become an impediment over time to sell carbon credits from Blue Carbon projects. This might point to the need to open a space for all actors in the market to explore how institutional arrangements could be created that effectively monitor and compensate for any reversals in BCE.

Whether or not carbon credits can be considered as a suitable funding source for BCE protection and restoration thus depends on how involved actors deal with associated integrity risks. Here, the use case is key as the risks can be reduced if buyers use the credits for other purposes than offsetting including contribution claims (while the quality of the certificate remains essential). Additionally, the effectiveness of carbon credits as a funding mechanism hinges on how integrity risks are addressed within the specific project context and the degree to which all involved actors prioritize and actively manage these risks.

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