SCIENTIFIC BEST PRACTICE GUIDES
FOR LAND-BASED CARBON PROJECTS

Blue Carbon

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The Nature Conservancy

Carbon accounting methods that center scientific best practices are the backbone of all rigorous approaches to carbon crediting. However, while decades of science have markedly increased the quality of carbon credits to date, research continues to evolve and improve project accounting.

The Scientific Best Practice Guides are a series of explainers on current scientific best practices and gaps for carbon projects developed in six emerging Natural Climate Solutions (NCS) pathways:

This Guide provides an overview of how high-quality **Blue Carbon** projects apply the latest scientific advancements and tools to create projects with high integrity in their definition of baseline scenarios, measurement and quantification of emissions reductions and removals, estimation of uncertainty, and monitoring of project activities and permanence. With this summary, buyers of high-quality carbon credits can better evaluate whether projects are effectively deploying rigorous scientific tools and approaches. For more detailed guidance on high-quality blue carbon projects, see the High-Quality Blue Carbon Principles and Guidance: A triple-benefit investment for people, nature, and climate report.

Natural Climate Solutions (NCS) pathways

1. Avoided Conversion of Grasslands and Shrublands (ACoGS)
2. Afforestation, Reforestation and Revegetation (ARR)
3. Agricultural Land Management (ALM)
4. Wetlands Restoration and Conservation (WRC): **Blue Carbon**
5. Improved Forest Management (IFM)
6. Reduced Emissions from Deforestation and Degradation (REDD)

What are Blue Carbon Projects?

Project activities depend on the context of the specific project and the methodology being used but must address the underlying cause of habitat loss or degradation. Causes of wetland degradation that could be mitigated with support from carbon finance include coastal development, aquaculture and agriculture, coastal infrastructure (resulting in tidal restrictions), and reduced water quality. The resulting degraded wetlands can be at further risk due to sea-level rise and erosion. Blue Carbon project activities may include:

Avoided habitat loss (from an identified and quantifiable threat) through avoiding planned or unplanned conversion or degradation

Restored tidal connectivity (e.g. removing tidal barriers, restoring tidal flow to tidally-restricted areas, etc.)

Rewetting drained organic soils (e.g. improving hydrological connectivity, etc.)

Restoring sediment to sediment starved wetlands (e.g. diverting river sediments, beneficial use of dredged materials, etc.)

Improved water quality (e.g. reducing nutrient inputs)

Replanted vegetation (e.g. reseeding or replanting of native plant communities)

These activities generate credits primarily from changes in five carbon pools and greenhouse gas (GHG) sources:

CO_2 — Carbon dioxide (CO_2) emissions removed from the atmosphere by plants and sequestered as soil organic carbon (SOC).

CO_2 — CO_2 emissions removed from the atmosphere by plants and sequestered in aboveground living biomass.

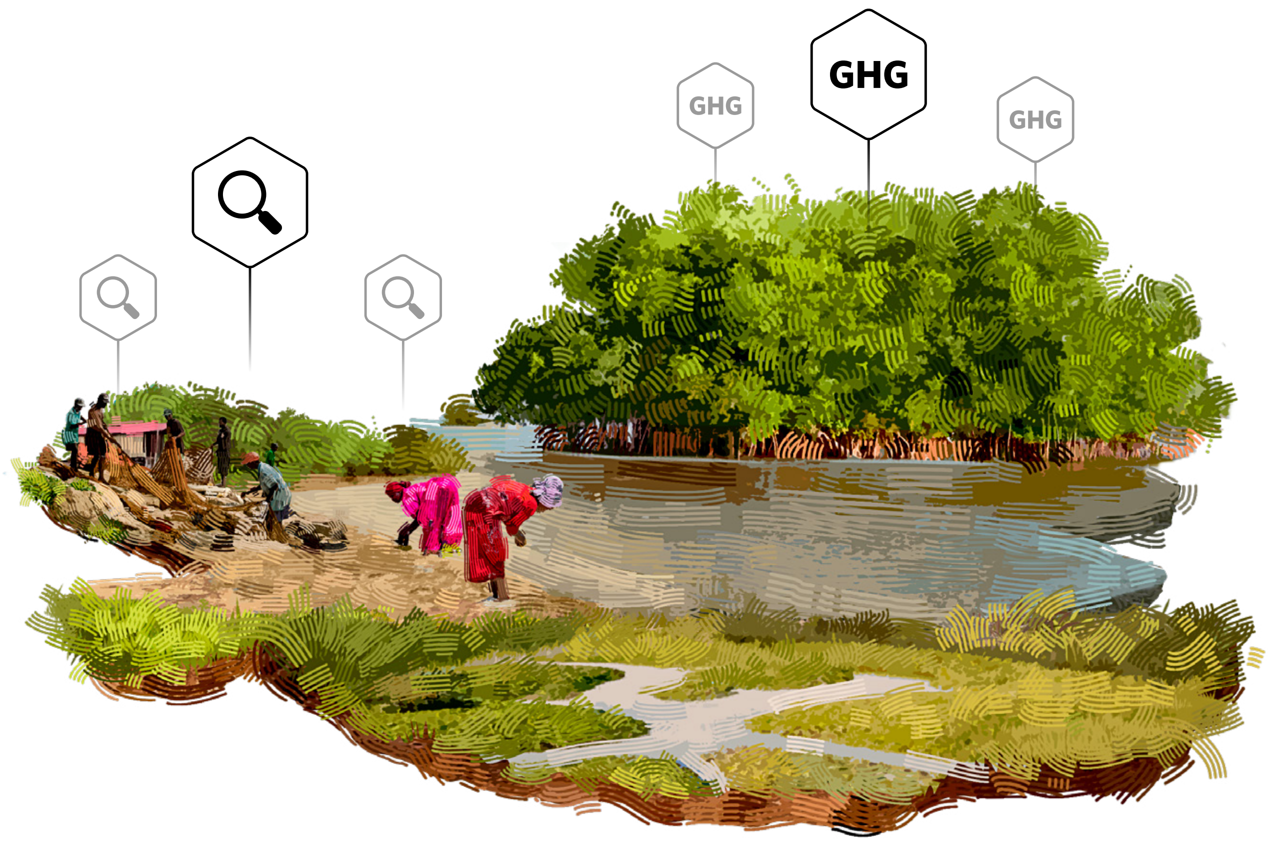
CO_2 — CO_2 emissions removed from the atmosphere by plants and sequestered in belowground living biomass (e.g., roots).

N_2O — Reduction in soil nitrous oxide (N_2O) emissions from soils to the atmosphere.

CH_4 — Reduction in soil methane (CH_4) emissions from soils to the atmosphere.

Blue Carbon projects generate carbon credits by implementing restoration and/or conservation (avoided loss) activities in coastal wetland habitats, including **mangroves, salt marsh and seagrass systems**. Though other habitats are being explored (e.g. kelp), the current science and approved methodologies limit blue carbon to these three vegetated coastal habitats (Howard et al. 2023). What distinguishes blue carbon from other pathways is the focus on the soil carbon pool (though other pools may be included in project accounting). Soil carbon represents a more permanent carbon pool (as long as the habitat remains intact and healthy) when compared to biomass carbon pools.

The coastal landscape is uniquely dynamic, making blue carbon market projects particularly challenging to implement. As such, the state of the science of blue carbon is constantly evolving and should be reevaluated regularly. A successful and high-quality blue carbon project balances environmental impact, community well-being, and legal compliance. Projects not only identify and quantify emissions from all pools and sources likely to be affected by the project activities within the project boundary, but also consider community benefits and needs. High-quality projects should leverage the best available science and best practices to achieve four core tasks:



1. Monitoring implementation of restoration or conservation activities before and after the project start date.

2. Quantifying GHG emissions reductions and removals under the baseline and project scenarios.

3. Engaging directly with local communities throughout project design and implementation.

4. Quantifying other ecosystem services such as enhanced biodiversity, water quality, coastal resilience, etc.[1]

Monitoring Project Activities

Carbon projects result in climate-positive behavior change that is driven or supported by market incentives. It is therefore essential to monitor blue carbon project conditions before and after the implementation of a carbon project to ensure that a practice change has been made and that the resulting climate benefit is due to that practice change. This documentation is a critical component of a project's demonstration of additionality relative to a business-as-usual baseline scenario.

Pre-Project Monitoring

DEMONSTRATING ADDITIONALITY

Under Verra's Verified Carbon Standard, the rate at which blue carbon restoration and protection projects are occurring globally is so low that most projects will meet additionality requirements, provided that they also meet the regulatory surplus test (i.e. project activities are not mandated by any enforced law, statute, or other regulatory framework). However, it is also recommended that projects demonstrate financial additionality (i.e. how carbon finance fills project budget gaps).

LEGAL CONSIDERATIONS

Coastal landscapes can be subject to varying landownership, affecting the extent of the crediting area. For example, intertidal areas may be owned or managed by multiple entities, and as sea levels rise, these boundaries may change as land is submerged. Even in cases where land ownership is clear, governments may lay claim to carbon rights as a national resource. **Project proponents will need to show clear rights to develop the project and who will own the credits generated.**

ESTABLISHING THE BASELINE

Credits in high-quality projects are quantified as the net impact of project activities on GHG emissions relative to a counterfactual baseline scenario in which the project was not implemented. **For blue carbon projects, the most credible baseline is usually the continuation of the historical land use in the 10 years leading up to the project start date.** For example, if a project aims to incentivize the restoration of tidal flow to an impounded wetland, the baseline scenario should represent the continuation of the wetland impoundment and its associated GHG emissions without the reintroduction of tidal flow. Detailed data on project activities are therefore needed for pre-project years as well as the duration of the project itself.

Coastal landscapes are dynamic and may be at risk of additional climate impacts that must be considered when planning a project. **Projects must account for potential risks to the integrity of the conservation or restoration activity resulting from climate change and extreme weather events (e.g. sea-level rise and hurricanes).**

The information necessary to satisfy all these monitoring and legal requirements include:

- **Project area delineation:** GPS coordinates, remote sensing data, and/or legal parcel records for the area where project activities are planned.
- **Emissions factors and sequestration rates:** Accurate data on emission factors (the rate at which GHGs are released) and sequestration rates (the rate at which GHGs are removed from the atmosphere).
- **Land management factors:** Detailed information about land use and management activities before and after project implementation.
- **Response to sea-level rise:** Projections of the effects of sea-level rise at the project site, including how the project will monitor changes in wetland distribution and elevation over time.
- **Permanence:** The carbon sequestration benefits must be protected for at least 40 years (noting some standards, e.g. Verra, require 100 years) or account for subsequent reversals. High quality projects include strategies to address risks (e.g. sea-level rise, natural disasters).
- **Leakage:** Projects must account for emissions caused outside of the project area due to project activities. For projects using the VCS VM0033 methodology, leakage is deemed not to occur if the applicability conditions of the methodology are met.
- **Unambiguous ownership:** The entity registering the carbon project must have clear ownership rights to the carbon credits.
  - In government-led projects, government land management agencies must be able to show statutory authority to participate in blue carbon projects. Typically, this authority enables collaboration with restoration funders, service providers, and other stakeholders.
  - In some geographies, there may be multiple stakeholder groups with varying rights to access and use land. Stakeholder mapping data is important to determine who would be impacted by project activities, positively or negatively.
  - Where land is privately owned, project proponents must assess local and national policies to determine if there may be government claim on the carbon or mineral rights.

High-quality carbon projects should use the same methods to quantify emissions and removals under *both* the baseline and project scenarios for the duration of the project's crediting period. Baseline scenarios should be evaluated every 6 years (as required by Verra) and reflect the emissions and removals that *would have occurred* during the project years had the project not been implemented. Using the same tools and methods for quantifying emissions and removals under each scenario ensures consistent carbon accounting that maintains the integrity of the baseline scenario while also reducing the uncertainty in the credits generated by the project (Zhou et al. 2023).

DEPLOYING REMOTE SENSING TECHNIQUES

To delineate an appropriate project area boundary, it is key to understand local land cover and land-use dynamics. Remotely sensed data and geographic information systems (GIS) serve as cost-effective tools to (1) map habitat extent and change (e.g., estimating loss rates), (2) identify risks or threats, and (3) quantify carbon stocks. Using combinations of spectral bands, vegetation indices derived from satellite imagery, and digital elevation models, coastal ecosystems can be classified at various points in time providing baseline extent maps and change through time.

In addition to spectral bands and vegetation indices, textural metrics derived from radar data and other three-dimensional structural metrics derived from Light Detection and Ranging (LiDAR) data can also be used to inform the classification but also to predict aboveground biomass (and subsequently aboveground carbon) in some cases, given the strong relationship between canopy structure and biomass for systems with mangroves. Additionally, repeat measures of these textural and structural attributes, along with vegetation indices can be used to track ecosystem health and condition (e.g., degradation) over time and highlight areas for restoration.

Some blue carbon ecosystems are easier to map and monitor with remote sensing approaches than others. For example, mangroves have unique spectral characteristics that lend themselves well to identification via earth observation data. They also sequester and store a significant amount of carbon aboveground in live biomass, which can be mapped and monitored with remote sensing. Seagrasses, because they are often subtidal, are more difficult to monitor via publicly available remote sensing data due to limitations of satellite imagery's ability to penetrate through the water column. It's thus important to understand the limits to the applicability of remote sensing in these different systems. Remote sensing tools also have inherent uncertainties, occasionally leading to misclassification of habitat cover or changes in cover. **All high-quality carbon projects that leverage remote sensing analyses to fill data gaps should follow appropriate protocols for identifying and reporting uncertainties via QA/QC methods like accuracy assessments and other performance metrics.** Working with land managers, these uncertainties can be addressed in a systematic way, improving the accuracy of the analyses through ground truth efforts and expert consultation/validation.

TIPS FOR BUYERS

- Ask who owns the land, who owns the credits, and how this was determined.
- Ask how the project area was delineated and what methods were used to ensure that only the lands implementing the project activities were included in project area.
- Ask to see historic imagery to verify project land use before project implementation.
- Ask how habitat degradation and conversion were measured and ask to see a report documenting accuracy and uncertainties in methods (if remote sensing data were used, this is generally in the form of an accuracy assessment report).
- Ask how the underlying cause of degradation was identified and how the project activities will directly address this.
- Ask if/how sea level rise will impact the project area, project activities and future GHG emissions. Ask if these impacts were considered in the project baseline.
- Ask what methods were used to quantify emissions and removals under the baseline and project scenarios.
- Ask how the project activities will be monitored through time (e.g., pre-project, during, and post-project).
    - If remote sensing or modeling methods are used, ask for documentation on the methods, and their accuracies (false positive and false negative rates)
    - Ask if there is a field validation plan to corroborate the methods applied and ask if stakeholders will be engaged to provide feedback that informs the outputs.

Quantification of Emissions Reductions and Removals

Quantifying Carbon Pools and GHG Sources

A core element of all carbon projects is the accurate quantification of the net GHG emissions reductions and removals achieved by a project while conservatively accounting for uncertainty in that number. This project-wide number is the sum of the project's impact on all carbon pools and GHG sources identified in the Project GHG Boundary. Different carbon pools and GHG sources often require different quantification methods to accurately estimate a project's impact. Different quantification methods include different types of uncertainty.

High quality carbon projects transparently outline both the quantification methods and types of uncertainty accounted for in all credited carbon pools and GHG sources.

The availability of existing blue carbon emissions and sequestration data can be limited in many geographies, and collecting these data can be difficult and costly to produce. To relieve this burden, Verra's current (undergoing updates as of the date of publication) coastal wetland restoration methodology (VM0033) allows project developers to utilize some default values[2], depending on the system and GHG pool/source (Table 1). Where local values are not available, these default values represent the best available data for Blue Carbon projects. However, projects that invest in local field data further improve the accuracy and reduce the uncertainty of the estimated credit volume.

Table 1: Quantification approaches for blue carbon GHG pools and sources using the VM0033 methodology.

GHG Pool/Source	Default	Proxy	Published/Modeled	Direct Measure
Herbaceous biomass C sequestration rate	3 tons/ha, scaled to 100% cover, one time	No	No	Field biology methods
Woody biomass C pool	No	No	No	Forest inventory methods
Soil C sequestration rate	1.46tons/ha/yr if at least 50% cover* Deduction for allocht[3] C if non-org soil	Same or similar systems	Same or similar systems	Soil cores with reference plane
Soil CH_4 emission rate	>18ppt** = 0.011 tons/ha/yr >20ppt** = 0.005 tons/ha/yr			Closed chamber or eddy covariance
Soil N_2O emission rate	Varies by salinity and by system			

*Soil C default (Chmura et al. 2003) may only be used in the absence of published values.
**Soil CH4 default (Poffenbarger et al. 2011) may only be used in the absence of published values.

Key considerations around the use of blue carbon quantification approaches include:

1. **Default emission factors may be used where scientifically credible and where there is no existing locally relevant published data.** Default values allowed include published data by the International Panel on Climate Change (IPCC) for use in national GHG inventories (tier 1), country-specific data for key factors (tier 2) or carbon stock data and emissions rates from a detailed inventory resulting from repeated measurements through time or modeling (tier 3). Tier 1 or 2 data may be accompanied by large error ranges, for example +/-50% for aboveground pools and +/-90% for the variable soil carbon pools; however, these default values are considered conservative and thus allowed unless more locally derived data is available.

2. Proxies are sometimes used to estimate GHG emissions; however, they are not well developed for blue carbon systems. A commonly used proxy is salinity to estimate methane, based on Poffenbarger et al. 2011, which suggests that for wetlands with salinities over 18ppt, methane emissions are negligible. However, new research (currently in publication, expected release 2024) suggests this range is more variable. **Proxies should be used cautiously.**

3. **Published values** may be used for the average rate of GHG emissions and can be a valid approach, provided they are derived from data published via peer-review and the data are **from the "same or similar" system as those in the project area.**

4. Models are another option for estimating GHG emissions; however, many current models are not yet adequately developed and tested for blue carbon. To be used, the model must be validated with direct measurements from a system with the same or similar water table depth, salinity, tidal hydrology, sediment supply and plant community as the project system. **All possible sources of model uncertainty should be assessed using recognized statistical approaches such as those described in the 2006 IPCC Guidelines.**

5. Field-collected data include directly measured GHG emission rates or carbon stock changes through field sampling. **To achieve robust blue carbon accounting through field sampling, stratification must be used to subdivide the project area into spatially explicit strata which are similar.** For example, strata may be chosen

based on soil type and depth, water table depth, vegetation cover, salinity, land type or expected changes in characteristics over the project lifetime. When measuring, increasing the number of strata will improve accounting accuracy by decreasing sample area.

As blue carbon GHG fluxes can vary, field collected data is the most reliable and accurate and should be prioritized where possible.

Collecting Data on Soil Carbon and GHG Fluxes

SOIL CARBON

SOC stocks (the density of organic carbon in the soil) should always be measured both at the start of a project and periodically (at least every 5 years) over the project's lifetime. The initial measurement represents the shared starting point for the baseline and project scenarios, which diverge from the initial SOC stock once the project starts. When determining SOC, soil cores are collected and analyzed for 1) soil depth, 2) dry bulk density, and 3) soil organic carbon content ($\%C_{org}$). Dry bulk density multiplied by soil organic carbon content yields carbon stock in units of mass per volume.

As noted above, SOC stocks should be measured using a stratified random sampling design. This approach splits a project area into small, homogenous units to reduce the measured variation in SOC stocks within each stratum. Soil samples should be collected and analyzed to enable the subsequent calculation of SOC stocks and changes in SOC stocks. The sampling density (number of samples per unit area) within each stratum should be chosen to balance the tradeoff between sampling costs and reductions in credits due to sample error. The optimal sampling density will depend on the specific geography and the associated variability in environmental attributes within that geography as well as the project activities being credited.

The current best practice for obtaining SOC data is to collect physical soil samples and send them to an accredited soil lab for analysis. This process is time consuming and expensive and can present a cost barrier to many projects, yet the data are crucial to the integrity of high-quality carbon projects. As default and national values tend to be conservative, locally collected data will not only be more accurate, but may also yield a higher number of credits generated. Buyers of high-quality carbon credits may consider investing in research efforts to reduce SOC measurement costs and increase potential credit generation.

Table 2: Comparison of lab techniques to determine percent organic carbon from The Blue Carbon Manual (Howard et al. 2014).

	Dry Combustion Method		**Wet Combustion Method**
	Elemental Analyzer	**Loss on Ignition (LOI)**	**H_2O_2 and Dichromate Digestion (Walkley-Black Method)**
Pros	Quantitative measure of carbon content	Semi-quantitative measure of organic carbon content; low cost and simple technology	Semi-quantitative measure of organic carbon content; low cost and simple chemistry
Cons	Requires special instrumentation; can be costly	Percent organic C determined from empirically derived relationships between carbon and organic matter	H_2O_2 does not always digest carbon equally; produces hazardous waste.

Another important element of measuring carbon sequestration is understanding the point at which carbon accumulation begins due to the project's activities. Some methodologies have strict requirements on installation of marker horizons as a main method by which to measure soil carbon accumulation after the project start. Coring alone will not tell you how much material has accumulated due to the project. There needs to be a time element involved, and market horizons are the most cost-effective method.

ABOVEGROUND AND BELOWGROUND BIOMASS

Aboveground living biomass (AGB) can be herbaceous (predominantly in marsh and seagrass) or woody (predominantly in mangrove), while belowground living biomass (BGB) is made up of roots and rhizomes. Protocols for measuring biomass carbon may differ across habitat types and densities. In many cases, allometric equations can be used to describe the relationship between measurable parameters (e.g. height, diameter at breast height, density, cover, etc.) and total biomass and are commonly used to avoid destructive measuring practices. **Equations used should be from the same or similar system, and/or species if possible, and be well established in the literature (i.e. peer reviewed).** The biomass of each type of plant material is then multiplied by the corresponding carbon conversion factor to yield the stocks for the aboveground carbon pool. A challenge in measuring carbon pools in blue carbon habitats can be accessibility. Mangrove forests can be particularly challenging to sample in, as they often have abundant stilt roots or pneumatophores, are surrounded by dissecting channels, and experience tidal cycles.

Mangroves are at times treated similarly to upland forests in terms of quantifying biomass; however, there are some key differences to consider in how mangrove biomass is assessed. For example, when sampling mangrove trees within a sample plot, it is recommended that all live trees should be measured (versus trees only 10 cm or greater in upland forest plots), or that subplots be used in sampling areas where smaller trees dominate. In many geographies, the dominant mangrove species have shorter aboveground structure, often called dwarf or scrub mangrove. The availability of appropriate allometric equations for use in dwarf mangrove systems is much more limited. The few existing equations for dwarf systems originate mostly from Florida, USA; however, the most accurate approach is to develop equations for the plants in the area of interest. Because of the high variability between species and across geographies, development of locally relevant allometric equations is a much-needed area of further research. Likewise, for BGB, there is limited existing allometric equations for use in mangroves, yet the BGB carbon pool can be a key component. There are a few allometric equations reported in the literature, and although some are conservative, additional studies that develop more regionally specific equations would be a valuable contribution to the field. To get a general estimate of belowground biomass, belowground to aboveground biomass ratios are often used. Default mangrove belowground to aboveground biomass ratios range from 0.29 to 0.96 (Howard et al., 2014).

For tidal marsh, it is important to differentiate between high, middle, and low marsh habitats when designing a sampling plan. The majority of carbon stored in tidal marsh is found in the belowground biomass and soils, whereas aboveground biomass is more significant in high marsh settings. For BGB, carbon pools can be estimated using developed allometric equations or direct measurements. Allometric equations can be developed for a particular species and location as the most accurate approach.

Seagrass AGB can vary seasonally and in some locations may be entirely lost during winter. Sub-tidal meadows will require snorkel or scuba equipment to sample, which can be resource intensive.

The timing of sampling in blue carbon habitats is important, as carbon pools can vary depending on season, soil moisture content and salinity. **It is important to have a well thought out sampling plan, which considers tide schedules, potential flood events, accessibility to sampling sites, whether sampling plots will be temporary or permanent, and how large the sampling area may need to be to capture a representative sampling of plants.** Sampling is recommended at peak growing season consistently from year to year, usually mid-late summer.

The Blue Carbon Manual (Howard et al. 2014) provides additional guidance and details for gathering AGB and BGB data in blue carbon habitats, including determining carbon content of palms and other non-tree vegetation, pneumatophores, and litter.

GHG FLUXES

GHG fluxes are the net emissions naturally absorbed and emitted by the project area, which are ultimately factored into the number of credits generated. Emissions used to quantify the flux can be determined using direct measurements or by proxy. When using direct measurements, the GHG flux is estimated between the soil and vegetation and atmosphere/water column through precise measuring or modeling. GHG fluxes can be precisely measured using eddy covariance towers or static chambers. There are benefits of either approach. While eddy covariance towers offer minimal monitoring labor, they can be cost prohibitive as they require purchasing expensive flux towers and sensors and paying personnel to perform complex data processing. Static chamber methods can be less expensive to install but require more time and effort to establish and monitor (and still require the purchase of sensors). Chambers require construction or purchase of boardwalks to avoid disturbing the site where the fluxes will be measured.

If using a proxy for GHG fluxes, changes in carbon stocks can be determined one of two ways: 1) stock-difference method, which estimates the difference in carbon stocks measured at two points in time (tier 3 estimate), or 2) gain-loss method, which estimates the difference in carbon stocks based on emission factors of specific activities and is derived from literature and country activity data (tier 1 and 2 estimates) (Howard et al 2014).

Whereas proxies can be used for CO_2 emissions, and for CH_4 emissions in cases where salinity is above 18ppt, direct flux measurements are needed to measure N_2O emissions and CH_4 at lower salinity. N_2O emissions are mostly related to aqua/agricultural inputs and are usually negligible unless the system has a source of nitrate loading (e.g. fertilizer runoff), whereas CH_4 production is directly related to salinity (Poffenbarger et al 2011).

The Blue Carbon Manual (Howard et al 2014) is a standard resource for methods on collecting and accounting blue carbon quantification. We have included some summarized information here, particularly on soil organic carbon and GHG fluxes that are of particular importance in blue carbon accounting. For additional information on steps to collect, analyze and calculate soil organic carbon, GHG fluxes, and for measuring aboveground and belowground biomass carbon in blue carbon ecosystems, please reference the manual: The Blue Carbon Manual – Coastal Blue Carbon: methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows

A demonstrated soil core pulled from the marsh.
Based on images by ©Stefanie Simpson

An example of GHG monitoring using static chambers and an established boardwalk. Based on images by ©NOAA

GHG Modeling

Coastal systems are highly dynamic; therefore, coastal biogeochemical models need to be very sophisticated and incorporate a large number of parameters. Coastal models are known to have high variability and are prone to error or oversimplification. If a developer chooses to use this approach, **models used to simulate the effects of the project activities on GHG reductions and removals should always be calibrated and validated against measured datasets of the same GHGs.** Model validation should transparently report model prediction errors and propagate that error to subsequent model simulations. High-quality carbon projects will have publicly available model validation reports that include all data used for calibration and validation and intuitively display them opposite model predictions as simple scatterplots. **Models used in projects to quantify SOC removals should be validated based on their ability to predict SOC stock changes and not simply SOC stocks.**

Very specific ground-truth data are needed to validate models used in high-quality blue carbon projects. The best data come from long-term studies (>5 years) where repeated measurements of the target GHG source or pool are made over time in paired plots where both the improved project activity and business-as-usual baseline activity are implemented. For blue carbon, such ground-truthed models are still being developed and require more field validation to be widely applicable. Studies that don't meet these criteria often only measure GHG sources and pools at a single point in time, limiting their utility for model validation. Buyers of high-quality carbon credits may consider investing in research studies to generate the data needed to rigorously validate process-based GHG models.

Accounting for Uncertainty

High quality projects that quantify multiple sources of uncertainty should conservatively account for the impact of that uncertainty on the number of credits issued to the project. Proper accounting for uncertainty creates a probability distribution around a point estimate of a project's climate impact. The final credit volume issued to a project can then be selected from this distribution to represent a conservative issuance based on the reported uncertainties. **High quality standards require projects to take uncertainty deductions in project accounting when there is a greater than 20% error with a 90% confidence interval or 30% error with a 95% confidence interval.** Because the uncertainty distribution is created from the uncertainty in the project's quantification methods, this crediting approach incentivizes projects that reduce uncertainty through steps like reducing model prediction error (improving model validation), investing in locally derived data, and reducing sample error (collecting more samples).

TIPS FOR BUYERS

- Ask for a report summarizing all GHG sources and pools credited by the project, their associated quantification methods, and the types of uncertainty that are accounted for.
  - Ensure the same quantification methods are used for both the baseline and project scenarios for each GHG source or pool.

- Ask what data is being locally collected from the project site, and what methods are being used. Are field measurements following protocols set out in The Blue Carbon Manual (Howard et al 2014)?

- Ensure that the final credit issuance conservatively accounts for uncertainty and risks by issuing less than the average expected credit volume of the project (i.e. contributes to a buffer pool, 20%+ on average for Blue Carbon projects, as the risk of sea-level rise alone can score a 20-point risk reduction.). Refining and minimizing the risk score requires a lot of site-specific data – an area where further investment is needed.

- For projects measuring SOC stocks and stock changes:
  - Ask if the project area has been stratified prior to collecting soil samples.
  - Ask if equivalent soil mass methods were used when calculating SOC stock changes.
  - Ask about sampling density and if sample error is accounted for in the final credit volume.
  - If alternative measurement methods are used, ask what the error in those methods is and if it is accounted for in the final credit issuance.

- For projects measuring above- and belowground biomass:
  - Ask if the project is using species/ locally relevant allometric equations, and if those equations have been peer reviewed.

- For projects modeling GHG emissions:
  - Ask to see the project's model validation report and ensure it shows a simple scatterplot of model performance for data from previous studies of the project activity.

- Ask how sea-level rise has been considered.

Engaging with Local Communities

Coastal blue carbon projects often involve diverse stakeholders and land with unclear tenure. Blue carbon projects may take place where these communities live and work and have significant impacts to local economies. High quality projects implement social safeguards to protect community rights, incorporate local ecological knowledge and leadership in all elements of project design and implementation, and ensure equitable access to land and carbon revenues. Best practices include:

- Establishing a free, prior and informed consent (FPIC) process
- Ensuring inclusive participation with Indigenous Peoples and local communities, women, youth and other marginalized groups in project planning, design and governance
- Establishing accessible feedback and grievance mechanisms
- Respect local land uses and cultures
- Empower local communities to define equitable revenue sharing (preferably enabling communities to yield a higher percentage of benefits as prices increase and compensating project developers with a fixed rate)
- Operate locally and contextually
- Design agreements and contracts that are transparent and equitable

For additional guidance to inform decisions and actions when working with blue carbon stakeholders, see the following resources:

- High-Quality Blue Carbon Principles and Guidance: A triple-benefit investment for people, nature, and climate
- Including Local Ecological Knowledge (LEK) in Mangrove Conservation & Restoration: A Best-Practice Guide for Practitioners and Researchers
- Human Rights Guide for Working with Indigenous Peoples and Local Communities

TIPS FOR BUYERS

- Ask if stakeholder mapping has been conducted and how the local community has been/is engaged in project planning and implementation.
- Ask to see a record of the FPIC process.
- Ask how gender has been considered in stakeholder outreach and involvement.
- Ask how language barriers have been addressed.
- Ask who has ownership of the project area and if the same entity will retain the carbon rights.
    - If the credit ownership has been transferred, how is the community benefiting from carbon revenues? Is the credit owner local to the community or are revenues largely going to external entities?
- Does the carbon revenue benefit sharing approach use percentages or fixed rates?

Blue Carbon Methodology Review

Few carbon standards offer methodologies to credit blue carbon projects, and there is substantial variation in the minimum requirements for the use of scientific tools across methodologies. The table below summarizes the existing methodologies published by the leading voluntary carbon standards.

Table 3: A summary of available coastal wetland methodologies.

Standard	Methodology	Year of Publication	Development Status	Market Type	In process of Updates
VCS	VCS VM0033 Methodology for Restoration of Tidal Wetlands and Seagrass Meadows, v2.0 (currently being updated to v2.1)	2023	Complete	Voluntary	x
VCS	VCS VM0007 REDD+ Methodology Framework (REDD+MF), v1.6 (currently being updated to v1.7)	2020	Complete	Voluntary	x
ACR	ACR Restoration of California Deltaic and Coastal Wetlands	2017	Complete	Voluntary	
China Certified Emissions Reduction Program (CCER)	The Methodology of Greenhouse Gas Emissions Voluntary Reduction Project: Mangrove Vegetation Creation (CCER-14-002-V01)	2023	Complete	Regulated	
Australia Carbon Credit Scheme (ACCS)	Carbon Farming Initiative—Tidal Restoration of Blue Carbon Ecosystems, using the Blue Carbon Accounting Model (BlueCAM)	2021	Complete	Regulated	
Plan Vivo (PV Climate V5)	PM001: Agriculture and Forestry Carbon Benefit Assessment Methodology	2023	Complete	Voluntary	x
Gold Standard	Methodology for Sustainable Management of Mangroves v1.0	2024	*In development*	Voluntary	In draft

Note: This list is meant to be inclusive at writing (May 2024) but not exhaustive and does not indicate methodology endorsement by The Nature Conservancy.

TIPS FOR BUYERS

- VCS VM0033 methodology requires projects to meet current scientific best practices. Conduct extra due diligence on projects verified under other methodologies to ensure they meet a similar level of rigor.
- Note that VM0007 and VM0033 methodologies are both pending updates. It is expected that the blue carbon modules in VM0007 will be moved to VM0033.

ENDNOTES

1 Note that this report does not define how to evaluate carbon projects' assessments of ecosystem services. For options on how to evaluate these benefits, see methodologies available as part of Verra's Sustainable Development Verified Impact Standard (SDVISta) or Climate, Community, Biodiversity (CCB) Standard.

2 A default value is 'global' emissions factor that is not site specific and may over- or under-estimate emissions/sequestration at a given site. These are developed usually by IPCC and approved for use under a given methodology. However, a high-quality emissions factor can (should) be measured site-specific in the field (tier 3).

3 Shorthand for 'allochthonous.' Allochthonous carbon is carbon that was sequestered in one location, transported, and deposited in another location.

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