



PEMSEA Regional Methodology for Blue Carbon Project Accounting

**A Harmonized Guide for Estimating Carbon Stocks, Sequestration, and GHG
Reductions in Coastal Ecosystems**



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February 2026

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About Us

Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) is a regional coordinating mechanism for the sustainable coastal and marine development in the East Asian Seas Region.

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1. INTRODUCTION

Blue carbon ecosystems, including mangroves, seagrasses, and tidal marshes, are globally significant carbon sinks. These ecosystems sequester atmospheric carbon dioxide (CO₂) in both biomass and sediments and provide critical co-benefits such as coastal protection, biodiversity enhancement, and support for local livelihoods. East and Southeast Asian countries have recognized their value and incorporated blue carbon protection and restoration into national climate and development strategies.

However, differences in measurement methods, carbon pool inclusion, and monitoring frameworks have created fragmentation and hindered comparability across blue carbon projects. These inconsistencies affect national greenhouse gas (GHG) inventories and voluntary carbon crediting.

To address this, PEMSEA developed a harmonized methodology to provide:

- A standardized accounting framework for blue carbon ecosystems;
- Compatibility with national GHG inventories;
- Technical alignment with voluntary carbon credit certification requirements.

The methodology draws on international guidelines and carbon-accounting methodologies, national and subnational technical regulations and methodologies, and regional field and monitoring protocols.

Key enhancements include expanded accounting of carbon pools and relevant GHG emissions, including soil carbon, CH₄, and N₂O; systematic uncertainty assessment and reporting; and integration of adaptive management and co-benefit indicators.

This methodology is intended to:

- Enable standardized project design and implementation;
- Facilitate participation in carbon markets;
- Support accurate, transparent, and comparable GHG accounting;
- Align with national and international climate commitments.

2. REFERENCES, ACRONYMS, AND DEFINITIONS

2.1 Methodological Basis and Source Documents

This methodological framework is supported by the following technical annexes, which provide ecosystem-specific carbon accounting methods and guidance:

- **Annex A:** Mangrove Ecosystems – Carbon Accounting Methods
- **Annex B:** Seagrass Ecosystems – Carbon Accounting Methods
- **Annex C:** Salt Marsh Ecosystems – Carbon Accounting Methods
- **Annex D:** Blue Carbon Ecosystems Mapping
- **Annex E:** Monitoring Environmental Parameters Influencing Blue Carbon Ecosystems

The methodology was developed through review and synthesis of international guidance, carbon-accounting methodologies, national and subnational methodologies and technical regulations, and regional field and monitoring protocols relevant to blue carbon accounting. These source documents inform the methodological basis of the methodology but do not independently govern projects assessed under the methodology. Full bibliographic details are provided in the References section.

Key methodological sources include:

International guidance and field protocols — IPCC Guidelines and Wetlands Supplement; Blue Carbon Initiative Field Manual.

Carbon-accounting and crediting methodologies — Verra VM0007 and VM0033; J-Blue Credit Guidelines; the 2023 Chinese CCER Mangrove Creation methodology (CCER-14-002-V01); and the 2022 Fujian mangrove restoration carbon-sink methodology.

National and regional technical guidance — relevant Chinese MNR regulations, Korean MRV guidance, Indonesian standards, and other national or regional methodologies.

Regional monitoring guidance — Core and Network System Monitoring Guidelines for Blue Carbon Ecosystems and related regional protocols.

2.2 Acronyms

AGB	Aboveground Biomass
BGB	Belowground Biomass
BD	Bulk Density
CF	Carbon Fraction
CH ₄	Methane
CO ₂	Carbon Dioxide
GHG	Greenhouse Gas
GIS	Geographic Information System
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
LOI	Loss on Ignition
MRV	Monitoring, Reporting, and Verification
N ₂ O	Nitrous Oxide
RS	Remote Sensing
SET	Surface Elevation Table
SOC	Soil Organic Carbon
UNFCCC	United Nations Framework Convention on Climate Change
UAV	Unmanned Aerial Vehicle (Drone)
VCS	Verified Carbon Standard

2.3 Glossary of Key Terms

Aboveground Biomass (AGB)

The total mass of living plant material above the soil surface, including tree trunks, branches, leaves, and stems.

Belowground Biomass (BGB)

The total mass of living root material beneath the soil surface, including fine roots and rhizomes.

Blue Carbon

The carbon stored in coastal and marine ecosystems, particularly in mangroves, seagrasses, and salt marshes.

Bulk Density (BD)

The mass of soil per unit volume, expressed in g/cm^3 .

Carbon Burial Rate

The rate at which carbon is deposited and stored in sediments over time, typically measured in $\text{Mg C ha}^{-1} \text{ yr}^{-1}$.

Carbon Credit

A tradable unit representing one metric tonne of carbon dioxide equivalent (tCO_2e) of verified greenhouse gas emission reduction or removal relative to an applicable baseline. In blue carbon projects, eligible climate benefits may include enhanced carbon removals or sequestration and avoided emissions resulting from the prevention of ecosystem conversion or degradation, subject to the requirements of the applicable crediting framework.

Carbon Fraction (CF)

The proportion of dry biomass that consists of carbon, expressed as a decimal mass fraction. Use an applicable ecosystem- and pool-specific value from the relevant annex or justified species- or site-specific measurements.

Carbon Sequestration

The removal of atmospheric CO_2 through biological or other ecosystem processes and its subsequent storage in biomass and soil carbon pools.

Carbon Stock

The total amount of carbon stored in an ecosystem's carbon pools, including AGB, BGB, SOC, litter, and deadwood. Carbon stock is reported as a total mass (Mg C) or as carbon stock per unit area (Mg C ha⁻¹), with the reporting basis clearly stated.

Gain-Loss Method

An accounting approach that estimates the change in a carbon pool over a defined period as the balance between carbon gains and carbon losses. Gains may include biomass growth, organic matter inputs, sediment carbon accumulation or burial, while losses may include decomposition, erosion, disturbance, biomass removal, or other relevant carbon-loss pathways. The data used may range from literature-based parameters to site-specific measurements, depending on data availability and the methodological approach applied.

Greenhouse Gases (GHG)

Gases that trap heat in the Earth's atmosphere, contributing to climate change. Key GHGs in blue carbon ecosystems include CO₂ (carbon dioxide), CH₄ (methane), and N₂O (nitrous oxide).

Loss on Ignition (LOI)

A laboratory technique used to estimate soil organic matter and carbon content by combusting samples at high temperatures (typically 550°C) and measuring mass loss.

Monitoring, Reporting, and Verification (MRV)

A structured process for quantifying, documenting, and verifying carbon stock and sequestration in blue carbon ecosystems to ensure compliance with carbon crediting and national inventory standards.

Remote Sensing (RS)

The acquisition of information about the Earth's surface without direct physical contact using satellite, airborne, UAV, radar, LiDAR, or other sensor systems. In blue carbon assessment, remote sensing is a key source of spatial information used to delineate ecosystem extent and project boundaries, support stratification, monitor ecosystem change, and derive activity data. Where appropriately calibrated and validated with field observations, remote sensing may also support estimation of selected biophysical characteristics such as vegetation cover, canopy structure, or biomass.

Root-to-Shoot Ratio

A coefficient used to estimate BGB from measured AGB. The ratio varies by species and environmental conditions.

Sediment Accretion

Deposition of organic and inorganic materials contributing to long-term SOC storage.

Soil Organic Carbon (SOC)

The organic carbon contained within the soil profile, derived from plant, microbial, and other organic matter and reported as a concentration, density, or stock.

Stock-Difference Method

An accounting approach that estimates the change in a carbon pool by comparing carbon stock estimates at two or more points in time. The difference between stocks at the initial and subsequent measurement periods represents the net stock change over that interval and may be divided by the elapsed time to estimate an annual rate of change. Measurements should use consistent sampling locations, methods, stratification, and carbon-pool definitions across monitoring periods.

2.4 Key Concepts in Measuring Blue Carbon

The following key accounting categories form the foundation for blue carbon measurement and reporting. These categories support methodological consistency across countries in East and Southeast Asia while accommodating differences in project objectives—such as national GHG inventory reporting, voluntary carbon crediting, or ecosystem conservation. Clear definition of these components ensures harmonized application of measurement approaches and facilitates alignment with regional and international standards.

Carbon Stock Assessment

Carbon stock assessment quantifies the current carbon content within blue carbon ecosystems. This includes carbon stored in:

- Aboveground biomass
- Belowground biomass
- Soil organic carbon
- Litter and deadwood (if applicable)

Project proponents must apply standardized field-based or remote sensing techniques to estimate carbon stocks per pool. These values form the baseline for future change detection and crediting.

Carbon Sequestration Rate

Carbon sequestration rate refers to the net rate at which carbon stocks increase over a defined period, typically expressed in $\text{Mg C ha}^{-1} \text{ yr}^{-1}$. Carbon stock change over time may be quantified using the Stock-Difference or Gain–Loss approaches. Supporting measurements such as sediment accretion, carbon burial, marker horizons, and radiometric dating may provide inputs to these approaches but do not constitute separate ecosystem-level accounting approaches.

Greenhouse Gas (GHG) Emissions

Relevant greenhouse gas emissions shall be accounted for where they are materially affected by project activities or differ between the baseline and project scenarios. Depending on the ecosystem and activity, these may include CO_2 , CH_4 , and N_2O . Applicability and quantification procedures are addressed in the baseline, project-scenario, and ecosystem-specific sections of the methodology.

Net Carbon Flux

The net transfer of carbon between an ecosystem and the atmosphere over a defined period, indicating whether the ecosystem acts as a net carbon sink or source.

Carbon Crediting

Carbon crediting is the process through which verified greenhouse gas emission reductions or removals are converted into tradable carbon credits under an applicable carbon-crediting standard or program. For blue carbon projects, eligible climate benefits may include enhanced carbon removals or sequestration and avoided emissions resulting from the prevention of ecosystem conversion or degradation. Eligibility, additionality, permanence, verification, issuance, and other crediting requirements are governed by the applicable crediting framework.

Monitoring, Reporting, and Verification (MRV)

Monitoring, Reporting, and Verification (MRV) systems are essential to ensure the ongoing credibility and sustainability of blue carbon projects. MRV systems provide a structured process for tracking carbon stocks, sequestration rates, and GHG emissions over time, ensuring that the data is accurate and can be used for carbon crediting or climate reporting.

3. PROJECT SCOPE AND ELIGIBILITY

Project applications must meet the scope and eligibility requirements established in this methodology to qualify for assessment under the methodology and the accompanying PEMSEA certification framework. These requirements are intended to ensure that project activities generate measurable climate benefits, are supported by appropriate accounting methods, and maintain environmental integrity.

3.1 Project Types and Activities

Sections 3.1.1 to 3.1.3 define the principal blue carbon project activity types currently covered by the methodology. Eligibility is subject to the requirements of this chapter and the ecosystem-specific accounting and monitoring provisions in Annexes A–C.

Emerging blue carbon activities for which the methodology does not yet provide dedicated quantification methods are addressed separately in Section 3.1.4 and are outside the current scope for quantification and certification.

3.1.1 Creation, Restoration, and Rehabilitation of Blue Carbon Ecosystems

Creation, restoration, and rehabilitation represent related but distinct interventions based on the pre-project condition and intended ecological outcome of the site. For purposes of the methodology:

Creation establishes a blue carbon ecosystem in an area where the target ecosystem or vegetation did not previously occur or where suitable new substrate or habitat has been created.

Restoration re-establishes the ecological condition and natural trajectory of a degraded or altered blue carbon ecosystem, including its hydrology, salinity regime, sediment processes, and native vegetation.

Rehabilitation repairs key ecological functions, habitat condition, and carbon-storage capacity in heavily altered or converted areas where full return to the historical ecosystem condition may not be feasible.

Creation may include establishment of mangrove, salt marsh, or seagrass vegetation on ecologically suitable non-vegetated areas or newly created substrates.

Restoration may include removal of tidal barriers, re-establishment of tidal exchange, rewetting, recovery of natural sediment regimes, or re-establishment of native vegetation in degraded ecosystems.

Rehabilitation may include conversion of retired aquaculture ponds or salt pans, invasive-species removal followed by native revegetation, or repair of heavily disturbed seagrass or wetland habitat.

All creation, restoration, and rehabilitation activities shall demonstrate ecological suitability for the target ecosystem in accordance with Section 3.2.

3.1.2 Conservation of Blue Carbon Ecosystems

Conservation activities protect existing blue carbon ecosystems from anticipated conversion, degradation, drainage, excavation, deforestation, or other disturbances that would otherwise result in loss of ecosystem carbon stocks or increased greenhouse gas emissions.

The principal climate benefit of conservation is the avoidance of emissions associated with ecosystem loss or degradation, together with the maintenance of existing carbon stocks and ongoing carbon sequestration processes.

Examples include:

- establishment or enforcement of protected or conserved areas;
- prevention of mangrove clearing, wetland drainage, or conversion to aquaculture, agriculture, infrastructure, or other land uses;
- community-based management agreements, patrols, or tenure arrangements that demonstrably reduce conversion or degradation risk;
- regulatory or management measures that maintain existing ecosystem condition and prevent carbon-stock loss.

For conservation projects, the baseline scenario shall demonstrate that conversion or degradation would reasonably be expected to occur in the absence of the project. Baseline and additionality requirements shall be addressed in accordance with Sections 3.4 and 8.

3.1.3 Improved Management of Existing Blue Carbon Ecosystems

Improved management activities modify ongoing management practices, hydrological conditions, or ecological processes within an existing blue carbon ecosystem to increase carbon removals, reduce greenhouse gas emissions, or improve carbon retention relative to the baseline condition.

This category differs from conservation in that the primary intervention is a change in the management or condition of an ecosystem that remains in place, rather than the prevention of an anticipated conversion or loss. It also differs from rehabilitation where the principal objective is to re-establish ecosystem structure or function following substantial degradation or loss.

Examples may include:

- improvement of tidal connectivity in hydrologically restricted wetlands;
- modification of water-management practices to improve wetland condition or reduce greenhouse gas emissions;
- reduction of grazing, harvesting, or other pressures that constrain ecosystem condition or recovery;
- invasive-species management that improves native ecosystem function and carbon accumulation; and
- management interventions that improve seagrass condition, water clarity, sediment stability, or other factors demonstrably linked to carbon storage or sequestration.

The incremental GHG benefit shall be quantified relative to the baseline and shall not be double counted with benefits attributed to conservation or rehabilitation activities.

3.1.4 Emerging Blue Carbon Activities

Certain emerging marine cultivation activities, particularly macroalgae cultivation and bivalve culture, are recognized for carbon accounting or crediting under selected national and voluntary frameworks. Technical approaches have been developed to quantify carbon accumulation, stock change, export, burial, or other carbon pathways associated with these activities.

However, their accounting and crediting treatment is not yet harmonized across existing blue carbon frameworks. The existence of a carbon measurement or accounting method does not necessarily establish eligibility for carbon crediting.

The current methodology does not provide dedicated quantification methods, baseline procedures, or monitoring requirements for macroalgae or bivalve aquaculture. These activities are therefore not currently covered for quantification and certification under the methodology. They may be considered for inclusion in future revisions following evaluation and adoption of appropriate accounting methods, eligibility criteria, and monitoring requirements.

Retirement or conversion of aquaculture ponds to mangrove, seagrass, salt marsh, or other eligible coastal wetland ecosystems shall be treated as a rehabilitation or restoration activity under Section 3.1.1 rather than as aquaculture-based carbon sequestration.

3.2 Geographical and Ecological Conditions

Projects must satisfy appropriate geographic, ecological, hydrological, and habitat conditions to support credible carbon accounting and maintain environmental integrity.

3.2.1 Location and Spatial Scope

Projects shall be located within coastal and marine areas supporting mangroves, salt marshes, and seagrass meadows within their natural intertidal or subtidal distributions.

The geographic applicability of the methodology shall reflect the natural distribution of the target ecosystem. Mangroves occur primarily in tropical and subtropical regions, while salt marshes and seagrass meadows extend into temperate and higher-latitude environments, including subarctic regions.

Ecosystem-specific methods, parameters, and estimation inputs shall be appropriate to the ecological and geographic conditions of the project site; requirements for data selection, validation, and use of default or site-specific parameters are addressed in Chapters 7 and 8 and Annexes A–C.

Creation, rehabilitation, and restoration sites shall demonstrate ecological suitability for the target ecosystem in accordance with Section 3.2.2.

3.2.2 Ecological and Habitat Suitability

- Target ecosystems shall be naturally suitable for the project area or capable of being restored to suitable ecological conditions.
- Project activities shall avoid significant adverse impacts on surrounding ecosystems, existing native habitats, and species of ecological or conservation importance.

- Planting and revegetation activities shall use native species appropriate to the local ecological setting. Introduction of invasive or ecologically inappropriate non-native species shall not be permitted.
- Baseline ecosystem condition shall be documented before project implementation using habitat, vegetation, and ecological indicators appropriate to the target ecosystem.
- Biodiversity and other ecosystem-condition indicators should be monitored where relevant to demonstrate ecological effects, identify unintended impacts, and document project co-benefits.

Environmental and biological monitoring shall be designed and implemented in accordance with Chapter 12 and Annex E. Biodiversity monitoring under the methodology supports environmental safeguards and assessment of co-benefits and does not constitute biodiversity-credit quantification or certification.

3.2.3 Hydrological and Soil Safeguards

Project activities shall maintain or restore hydrological and soil conditions appropriate to the target blue carbon ecosystem and protect existing soil carbon stocks.

Hydrological interventions shall support appropriate tidal exchange, inundation, and water-table conditions and shall avoid significant adverse hydrological effects on adjacent ecosystems. Potential off-site effects shall be assessed in accordance with Chapter 10.

Project activities shall minimize unnecessary disturbance of organic-rich soils and avoid practices that result in significant carbon-stock losses. Sediment addition or replenishment may be undertaken where ecologically justified and where adverse impacts on surrounding habitats are avoided.

The assessment and quantification of GHG emissions associated with changes in hydrology, soil disturbance, salinity, or nutrient inputs shall follow Chapter 9 and the relevant ecosystem-specific annexes. Environmental monitoring requirements are provided in Chapter 12 and Annex E.

3.3 Project Area Eligibility, Tenure, and Rights

The project proponent shall demonstrate eligibility of the land or marine area within the project boundary through verifiable evidence of tenure or use rights, alignment with the crediting period, and documentation of prior land use and vegetation status.

3.3.1 Tenure and Rights

- Legal ownership or long-term use rights for land and marine areas within the project boundary must be clearly documented.
- Accepted evidence may include government-issued certificates, land or resource tenure maps, permits, formal agreements, or other official designations demonstrating applicable rights.

3.3.2 Crediting Period Alignment

- The project proponent shall maintain sufficient ownership, tenure, resource-use, or other legally recognized rights to implement the project activities and support the claimed GHG benefits throughout the applicable project and crediting period.
- Areas for which the required ownership, tenure, or use rights cannot be demonstrated shall not be included in verified GHG claims or credit issuance.
- Rights to claim the GHG emission reductions or removals generated by the project shall be demonstrated through statutory, contractual, or other legally recognized arrangements among project proponents, rights holders, relevant government agencies, and other stakeholders, as applicable.
- Any additional documentation requirements or phased tenure requirements for validation, verification, or issuance shall be established by the applicable PEMSEA certification framework.

3.3.3 Prior Land Use and Vegetation Status

- Project areas shall not be eligible where a native ecosystem has been intentionally cleared, drained, converted, or degraded for the purpose of creating eligibility for GHG crediting.
- Any historical look-back period, cut-off date, or pre-project vegetation criterion required to demonstrate eligibility shall follow the applicable ecosystem- or activity-specific provisions of this methodology and the PEMSEA certification framework.
- For creation, restoration, or rehabilitation activities, pre-project ecosystem and vegetation conditions shall be documented sufficiently to demonstrate that the claimed project activity and resulting GHG benefits are additional to the existing condition.
- Where natural regeneration is already occurring, project documentation shall demonstrate that the claimed project outcome is unlikely to be achieved without the project intervention.

- For restoration or rehabilitation of areas previously used for commercial or productive activities, the project proponent shall assess the potential for activity-shifting leakage in accordance with Chapter 10.

3.3.4 Transparency and Exclusivity

- Landholder, resource-user, and other relevant rights associated with each project parcel shall be disclosed and documented.
- Areas already registered or credited under another GHG crediting program shall be fully disclosed and excluded from overlapping credit claims to prevent double counting.

3.4 Demonstration of Additionality

Additionality demonstrates that the greenhouse gas (GHG) emission reductions or removals attributed to a project would not reasonably be expected to occur in the absence of the project activity.

Baseline determination and additionality assessment are related but distinct. The baseline scenario, established in accordance with Chapter 8, represents the most plausible conditions and GHG trajectory in the absence of the project. Additionality shows that the proposed project would not be expected to occur under the baseline scenario.

All projects seeking certification shall demonstrate additionality through regulatory surplus and one of the additionality pathways described below, as applicable to the project activity and the requirements of the PEMSEA certification framework.

3.4.1 Regulatory Surplus

The project proponent shall demonstrate that the project activity is voluntary and is not already required by applicable law, regulation, permit condition, legally binding administrative order, contractual obligation, or other mandatory requirement.

Compliance with existing legal obligations shall not, by itself, constitute an additional project activity. Where only part of a project exceeds the applicable legal or regulatory requirement, additionality shall be demonstrated for the portion of the activity for which GHG benefits are claimed.

3.4.2 Standardized or Activity-Based Additionality

Where an activity method, positive list, or other standardized additionality approach has been formally adopted under this methodology or the PEMSEA certification framework, a project may demonstrate additionality by satisfying the specified applicability conditions.

Such standardized approaches shall be based on documented evidence showing that the eligible activity is not already expected under prevailing conditions, for example through low activity penetration, lack of commercial attractiveness, or other criteria established in the approved method.

Project proponents shall not independently define a low-penetration threshold or claim automatic additionality solely because an activity is uncommon, publicly funded, non-profit, or undertaken for environmental or social purposes.

Where a standardized approach applies, project-specific investment or barrier analysis may be omitted only where the approved method explicitly allows this.

3.4.3 Project-Specific Additionality Assessment

Where no applicable standardized additionality approach has been adopted, additionality shall be demonstrated using a project-specific assessment appropriate to the project context.

The assessment may include:

- Common-practice analysis, evaluating whether comparable activities are already widely implemented under similar geographic, ecological, regulatory, technological, and socioeconomic conditions without reliance on carbon crediting;
- Barrier analysis, identifying material financial, technological, institutional, capacity, tenure, or other barriers that prevent or substantially constrain implementation; and
- Investment or financial analysis, demonstrating that the project is financially unattractive or less attractive than a credible alternative without carbon-credit revenue or other relevant project support.

The specific combination and sequence of tests shall follow the approved additionality procedure applicable to the project. The methodology does not require every project to apply all three tests where the applicable procedure establishes a different decision pathway.

Where common-practice analysis is used, the geographic and technical scope, definition of comparable activities, data sources, and any quantitative thresholds shall be clearly defined and justified.

Where barrier or investment analysis relies on carbon-credit revenue as the factor enabling project implementation, the project proponent shall demonstrate the material role of that revenue in overcoming the identified barrier or improving project viability.

3.4.4 Public-Benefit and Externally Supported Projects

Public, non-profit, community-based, or publicly funded projects are not automatically additional solely because they do not generate commercial profits.

Public-benefit status, grant funding, subsidies, or other external support may form part of the evidence used in the additionality assessment, provided that the project proponent demonstrates that the claimed GHG benefits exceed mandatory obligations and would not reasonably occur under the baseline scenario without the relevant project intervention or support.

Where an approved standardized methodology explicitly recognizes a class of public-benefit activities as additional, that treatment may be applied subject to the stated eligibility conditions.

3.4.5 Documentation of Additionality

The project proponent shall document:

- the additionality pathway and tests applied;
- evidence supporting regulatory surplus;
- the assumptions, data sources, geographic scope, and comparison activities used in any common-practice assessment;
- evidence supporting any barrier, investment, or financial assessment;
- the applicability conditions for any standardized or positive-list approach used; and
- the relationship between the additionality assessment, the baseline scenario in Chapter 8, and the GHG benefits quantified under Chapter 9.

Additionality claims shall be sufficiently documented to support independent validation in accordance with Chapter 13.

4. PROJECT BOUNDARIES

Project boundaries define the physical, geographic, and accounting limits of blue carbon activities. These boundaries ensure that carbon benefits are attributable, measurable, and clearly separated from non-project areas.

4.1 Geographical Boundaries

The geographical boundaries shall be established at validation and consistently tracked; subsequent changes shall occur only where justified and documented under the methodology. Project boundaries shall be defined using maps, unique identifiers, and precise geographic coordinates, and must represent the full extent of the area subject to accounting and intervention.

4.1.1 Methods for Boundary Delineation

Project boundaries shall be delineated using a combination of remote sensing data, field surveys, and geographic information systems (GIS), as described below.

a. Remote Sensing and Imagery

- High- or moderate-resolution satellite imagery (e.g., Landsat, Sentinel) or aerial photographs to delineate ecosystem distribution and land cover.
- Synthetic Aperture Radar (SAR) to detect mangrove structure, canopy extent, or inundation patterns.
- Unmanned aerial vehicles (UAVs) or drone imagery for small-scale or complex features (e.g., aquaculture ponds).
- Publicly available imagery (e.g., Google Earth) for supplementary visual validation.
- National or local spatial datasets (e.g., mangrove inventories, zoning plans), if available.

b. Field Surveys and Ground-Truthing

- Use of GNSS receivers, including GPS-enabled devices, to mark polygon vertices and inflection points with meter-level positional accuracy (typically $\pm 1-2$ m).

- Field validation of remotely derived boundaries through direct observation: walking or boating along habitat edges, snorkeling/diving for submerged zones, or confirming vegetation type.
- Integration of local ecological knowledge or citizen science input through mobile GIS tools.

c. GIS Integration

- GIS platforms shall be used to integrate and finalize boundary polygons based on satellite, aerial, and field data.
- GIS tools may also support systematic gridding and stratification for sampling design.

4.1.2 Boundary Documentation Requirements

Project proponents shall submit the following information as part of boundary documentation:

- Georeferenced digital maps of the project area and its strata, showing administrative boundaries and ecosystem types.
- Complete coordinates of project boundary vertices (latitude/longitude to at least six decimal places).
- Description of boundary delineation methods, including imagery sources, classification techniques, field validation protocols, and error tolerances.
- Justification for area calculations, including any stratification based on ecological parameters (e.g., vegetation type, soil depth, salinity, bathymetry, disturbance history).
- Identification and justification of areas excluded from the accounting boundary. Intact ecosystems included in an eligible conservation activity shall not be excluded solely because no planting or physical restoration occurs.
- Consideration of dynamic ecological processes such as potential landward wetland migration or projected sea level rise.
- Baseline and monitoring period comparisons, where applicable, using time-series satellite imagery.

4.2 Temporal Boundaries

Temporal boundaries define the periods used to establish the baseline condition, identify the start of project activities, quantify project-induced changes, and support crediting and monitoring. Temporal components shall be defined consistently with the project activity, available data, and the requirements of the methodology and PEMSEA certification framework.

4.2.1 Historical Reference Period

The historical reference period provides the temporal basis for establishing pre-project conditions and, where relevant, trends in ecosystem extent, land use, carbon stocks, or greenhouse gas emissions.

For projects in which the baseline depends on historical land-use or ecosystem-change trends, a reference period of approximately 10 years prior to the project start date should normally be used where suitable data are available.

Where a multi-year historical trend is not required or cannot be reliably reconstructed, a clearly defined baseline or inventory year may be used, provided that:

- the selected year is representative of pre-project conditions;
- the choice is supported by appropriate spatial, field, or historical evidence; and
- the resulting baseline remains conservative and consistent with the baseline procedures in Chapter 8.

4.2.2 Project Start Date

The project start date is the date on which implementation of the eligible project activity begins and from which project-induced changes may be attributed to the intervention.

The project start date shall be clearly documented and supported by verifiable records such as implementation agreements, field records, dated imagery, planting or restoration records, or other appropriate evidence.

4.2.3 Crediting Period

The crediting period is the period over which verified net GHG benefits may be considered for credit issuance under the PEMSEA certification framework.

The duration, renewal conditions, and any limits on retroactive crediting shall be specified in the PEMSEA certification framework. The methodology does not assign different crediting periods solely on the basis of ecosystem type unless an ecosystem-specific requirement is scientifically or methodologically justified.

4.2.4 Baseline Reassessment and Monitoring

Baseline assumptions and temporal parameters shall be formally reassessed at intervals not exceeding 10 years and earlier where material changes occur in project boundaries, land or marine use, ecosystem condition, management practices, or other factors that materially affect the validity of the baseline. Where an ecosystem-specific provision requires a shorter reassessment interval, the shorter interval shall apply.

Baseline reassessment shall follow the procedures in Chapter 8, while monitoring and remeasurement frequencies for individual carbon pools and environmental parameters shall follow Chapter 12 and Annexes A–E.

4.2.5 Permanence and Reversals

The crediting period and permanence obligation are distinct concepts. A crediting period defines when project benefits may be quantified and credited; it does not by itself define how long credited carbon must remain stored.

Requirements for permanence, reversal management, and any associated risk-management or compensatory mechanism shall be addressed under Chapter 11 and the PEMSEA certification framework.

4.3 Carbon Pools

Carbon pools that are materially impacted by project activities and contribute to quantifiable changes in greenhouse gas emissions or removals must be accounted. Carbon pools are categorized based on their association with living biomass and non-living organic matter in the project area.

4.3.1 Definition of Carbon Pools

Carbon pools refer to reservoirs of carbon stored in biomass and organic matter within the project boundary. The following pools are recognized for coastal blue carbon ecosystems:

- Aboveground biomass (AGB): Carbon stored in living plant tissue above the soil surface, including stems, branches, and leaves.
- Belowground biomass (BGB): Carbon stored in living roots, including coarse and fine roots.

- Soil organic carbon (SOC): Organic carbon contained in the soil profile, primarily resulting from plant inputs and microbial activity.
- Deadwood: Non-living woody biomass lying on the surface or standing, not attached to living plants.
- Litter: Organic material such as fallen leaves, twigs, and non-woody debris above the soil.

Other pools such as harvested wood products or inorganic carbon are excluded from this methodology.

4.3.2 Eligible Pools per Ecosystem Type

The relevance and measurability of carbon pools vary across ecosystems. Table 1 summarizes which carbon pools are generally included in mangroves, seagrasses, and other coastal wetlands.

Table 1: General applicability of carbon pools across coastal ecosystem types

Carbon Pool	Mangroves	Seagrasses	Salt Marshes	Notes
Aboveground biomass	Required	Optional	Required	In seagrasses, may be minimal or excluded depending on biomass presence.
Belowground biomass	Required	Required	Required	Important in all ecosystems due to high root carbon content.
Soil organic carbon	Required	Required	Required	Minimum 1 meter depth recommended unless otherwise justified.
Litter	Optional	Not Applicable	Optional	Include where significant, especially in mangroves.
Deadwood	Optional	Not Applicable	Not Applicable	Include in mangroves if present and measurable.

Note: The classifications in Table 1 indicate the general applicability of each carbon pool. Pool inclusion and exclusion shall be determined in accordance with Section 4.3.3 and the applicable ecosystem-specific provisions in Annexes A–C. A pool identified as “Required” shall normally be included unless its exclusion is explicitly permitted or otherwise justified under those provisions.

The ecosystem-specific annexes provide further details on default practices, field measurement options, and guidance on selecting appropriate pools.

4.3.3 Pool Inclusion and Exclusion Criteria

Carbon pools that are materially affected by the baseline or project scenario and contribute to the estimation of net GHG benefits shall be included in project accounting, subject to the ecosystem-specific requirements in Annexes A–C.

A carbon pool may be excluded where:

- the pool forms part of the cumulative project-level de minimis exclusions described in Section 10.4, and the combined contribution of all excluded carbon pools, GHG sources, and leakage sources remains below the applicable threshold; or
- exclusion of the pool is explicitly prescribed or otherwise justified under the applicable ecosystem-specific provisions of this methodology.

A pool shall not be excluded where its omission would result in systematic overestimation of project GHG benefits. In particular, carbon-stock losses or other adverse changes that are materially affected by project activities shall be accounted for where their omission would make the project benefit appear greater than it is.

All pool exclusions shall be documented, including the basis for exclusion and any supporting calculations or methodological provisions.

4.4 Stratification of Project Area

Stratification is the process of dividing a project area into smaller, more homogeneous sub-areas (strata) based on ecological, physical, and land-use characteristics. Stratification improves the accuracy and representativeness of carbon stock and sequestration estimates by accounting for variation across the landscape.

Projects must stratify the project area using relevant biophysical or management variables known to influence carbon stocks and fluxes.

4.4.1 Criteria for Defining Strata

Strata should be delineated based on site characteristics known to influence carbon stocks and fluxes, which may include:

a. Vegetation Characteristics:

- Species composition, structural type (e.g., trees, shrubs, grasses), canopy density, or dominant growth form.
- Examples include tall vs. dwarf mangroves, grass- vs. shrub-dominated salt marshes, and deep vs. shallow seagrass beds.

b. Soil and Sediment Properties:

- Soil depth, sediment type (e.g., mineral vs. organic-rich), grain size, bulk density, and organic carbon content.

c. Hydrological Conditions:

- Frequency and depth of tidal flooding, salinity gradients, and tidal connectivity.
- Strata should distinguish between areas with unrestricted tidal exchange, reduced flooding, and impounded or modified water regimes.

d. Geomorphological Features:

- Elevation, proximity to tidal channels or shorelines, and transitions between upland and intertidal zones.

e. Land Use and Disturbance History:

- Historical or current land use (e.g., aquaculture, dredging) that may affect baseline conditions or project outcomes.

4.4.2 Methods and Tools for Stratification

a. Remote Sensing and GIS

High-resolution satellite imagery, aerial photographs, LiDAR, and spatial databases can be used to delineate ecological zones, vegetation types, and topographic variation.

b. Ground-Truthing

Field validation, including local knowledge, GPS mapping, and direct observation (e.g., in subtidal areas), is essential to verify and refine strata.

c. Preliminary Field Surveys

Rapid field assessments can provide additional insight into belowground conditions (e.g., sediment type, soil depth) or ecological gradients not evident in imagery.

4.4.3 Sampling Design Within Strata

a. Representative Plot Selection:

Plots should be located using probabilistic or systematic designs to ensure unbiased and representative sampling within each stratum. Grid-based or randomized sampling approaches are recommended.

b. Plot Types and Sizes:

The plot size and shape should balance measurement accuracy, field efficiency, and cost.

- Nested plot designs may be used to accommodate multiple carbon pools (e.g., large plots for trees, subplots for seedlings or litter).
- Linear transects may be employed in dense vegetation (e.g., mangroves) to facilitate access and minimize disturbance.

c. Number of Plots:

The number of plots per stratum shall be determined from expected variability, the sampling design, and the precision and confidence requirements applicable to the accounting component. Sample-size calculations and achieved precision shall be documented in accordance with Chapter 6 and the relevant ecosystem-specific annex.

5. GENERAL CARBON ESTIMATION METHODS

Quantification of carbon stocks and greenhouse gas (GHG) benefits in blue carbon projects relies on two principal approaches: the stock-difference method and the gain–loss method. These approaches are applied across relevant carbon pools to estimate net removals, sequestration rates, or avoided emissions. Standardized equations are used to calculate pool-specific carbon stocks, which are then scaled and converted to CO₂ equivalents for reporting. Estimation procedures follow general principles outlined here, with ecosystem-specific details provided in the annexes.

5.1 Carbon Sequestration Estimation Approaches

Two general methods are used to quantify carbon sequestration over time:

a. Stock-Difference Method

This method quantifies the change in carbon stock by comparing total carbon at two time points (T1 and T2):

$$\Delta C = (C_{t2} - C_{t1}) \quad \text{Equation 1}$$

where ΔC is the net change in carbon stock (Mg C).

$$\text{Annual Sequestration Rate} = \frac{\Delta C}{\Delta T} \quad \text{Equation 2}$$

where ΔT is the number of years between measurements.

This approach applies to each carbon pool and is most appropriate for projects with plot-level measurements at multiple time points.

b. Gain-Loss Method

This method estimates net sequestration as the balance between gains (e.g., growth, deposition) and losses (e.g., decomposition, disturbance):

$$\text{Net Sequestration} = \text{Gains} - \text{Losses} \quad \text{Equation 3}$$

This method is useful in systems where stock measurements are not repeated or in restoration contexts where fluxes dominate.

5.2 Carbon Stock Estimation Approaches

The following equations represent typical calculations used for estimating carbon stocks in various ecosystem components.

a. Aboveground Biomass (AGB)

AGB is typically calculated using allometric equations:

$$AGB = a \times (DBH^b) \times (H^c) \times \rho^d \quad \text{Equation 4}$$

Where:

- AGB = Aboveground biomass (in kg)
- DBH = Diameter at breast height (in cm).
- H = Height of the tree (in meters).
- ρ = Wood density (in g/cm³).
- a, b, c, d = Coefficients specific to the species or forest type.

Carbon stock is then estimated as:

$$C_{AGB} = AGB \times CF \quad \text{Equation 5}$$

where CF is the carbon fraction (e.g., 0.47 for mangroves).

b. Belowground Biomass (BGB)

Estimated by applying a root-to-shoot ratio to AGB:

$$BGB = AGB \times \text{Root to Shoot Ratio} \quad \text{Equation 6}$$

Carbon stock is then estimated as:

$$C_{BGB} = BGB \times CF \quad \text{Equation 7}$$

c. Soil Organic Carbon (SOC)

SOC stock per unit area is calculated as:

$$SOC (MgC/ha) = D \times BD \times C_{org} \times 100 \quad \text{Equation 8}$$

Where:

- D = Sampling depth (in cm)
- BD = Bulk Density (in g/cm³).
- C_{org} = organic carbon concentration (expressed as a decimal mass fraction)

The factor 100 converts units to Mg C/ha.

d. Litter and Deadwood

Where included, these are calculated using:

$$C_{Litter} \text{ or } C_{Deadwood} = Biomass \times CF \quad \text{Equation 9}$$

These generalized approaches are useful for comparability across project types. However, it is important to note that other methods may also be applicable and are detailed in the respective ecosystem annexes. For example, Aboveground Biomass (AGB) may be estimated using Biomass Expansion Factors (BEF) instead of allometric equations in some contexts, and Belowground Biomass (BGB) may also be directly estimated using ecosystem-specific allometric models or root sampling techniques.

5.3 Reporting Framework

Carbon stock values are first reported at the plot level per carbon pool, then scaled up to the stratum and project level using area-weighted averaging.

If time-based measurements are available, sequestration rates are reported as:

Mg C/ha/year, then scaled by project area to obtain Mg C/year

5.4 Conversion to CO₂e

Carbon stock changes and sequestration rates are converted to CO₂ equivalents for climate reporting:

$$CO_2 e = C \times \frac{44}{12} \quad \text{Equation 10}$$

where 44/12 is the molecular weight ratio of CO₂ to C.

The 44/12 ratio converts carbon-stock changes and carbon sequestration expressed as carbon mass to the corresponding CO₂ mass. CH₄ and N₂O emissions shall be converted to CO₂ equivalents using the applicable 100-year GWP values specified in Section 5.5.

5.5 GHG Emissions

Where applicable, projects shall quantify relevant emissions of CO₂, CH₄, and N₂O in accordance with Chapter 9 and the ecosystem-specific annexes. Non-CO₂ GHG emissions shall be converted to CO₂ equivalents using 100-year Global Warming Potential values applicable to the relevant national inventory or certification framework. The GWP source and values used shall be documented.

5.6 Reference to Annexes

Detailed procedures for field measurements, laboratory analysis, and estimation methods specific to mangroves, seagrasses, and salt marshes are provided in Annexes A–C.

6. UNCERTAINTY MANAGEMENT AND REPORTING

Transparent GHG accounting requires systematic identification, quantification, propagation, and reporting of uncertainty associated with carbon stocks, carbon-stock changes, GHG emissions and removals, activity data, and spatial estimates. Uncertainty may arise from measurement, sampling, model selection, parameter values, spatial delineation, temporal variability, and other sources.

This chapter establishes the general uncertainty framework applicable across project types and ecosystems. Ecosystem-specific procedures and precision requirements are provided in the relevant annexes.

6.1 Sources of Uncertainty

Uncertainty may originate from one or more of the following sources:

a. Measurement Uncertainty

Errors or variability associated with field measurements, instruments, laboratory analyses, and analytical procedures.

b. Sampling Uncertainty

Variability arising from natural spatial heterogeneity and the use of a sample to represent a larger population, stratum, or project area.

c. Parameter and Model Uncertainty

Uncertainty associated with the selection and application of allometric equations, biomass expansion factors, carbon fractions, root-to-shoot ratios, emission factors, default values, process models, and other estimation relationships or parameters.

d. Area and Classification Uncertainty

Uncertainty associated with delineating the spatial extent of ecosystem strata using remote sensing, GIS, or field-based approaches.

e. Temporal Uncertainty

Variability associated with seasonal conditions, monitoring intervals, annualization, interpolation, or extrapolation between measurement periods.

All material sources of uncertainty shall be identified and addressed using methods appropriate to the parameter and accounting approach.

6.2 Quantification of Uncertainty

Uncertainty shall be quantified separately for relevant input parameters and accounting components where practicable.

For estimates derived from field sampling, sampling uncertainty may be expressed using the standard error of the mean, confidence intervals, relative error, or other statistically appropriate measures.

$$SE = \frac{s}{\sqrt{n}} \quad \text{Equation 11}$$

Where:

- SE = standard error of the mean
- s = sample standard deviation; and
- n = number of independent sampling units

Where the sampling design involves stratification, clustering, weighting, or other complex design features, the standard error shall be calculated using a method appropriate to that design.

Other uncertainty components, including measurement, parameter, model, and spatial uncertainty, shall be quantified using appropriate statistical, analytical, validation, or error-propagation methods.

Relative uncertainty may be expressed as the half-width of the applicable confidence interval divided by the estimated mean. The confidence level used shall be stated and shall follow any requirement specified in the relevant ecosystem-specific method or certification framework.

6.3 Combination of Uncertainties Across Carbon Pools and Strata

a. Across Carbon Pools

Where uncertainty estimates for included carbon pools are independent or may reasonably be treated as independent, their sampling uncertainties may be combined using root-sum-of-squares (RSS) propagation:

$$SE_{C,total} = \sqrt{\sum_{j=1}^m SE_{C,j}^2} \quad \text{Equation 12}$$

Where:

- $SE_{C,total}$ = combined standard error of the carbon-stock estimate
- $SE_{C,j}$ = standard error associated with carbon pool j ; and
- m = number of included carbon pools

Equation 12 applies where the component estimates are expressed in compatible units and the independence assumption is reasonable.

b. Across Strata

Where carbon density is estimated separately for multiple strata, the standard error of the total project carbon stock may be calculated as:

$$SE_{C,project} = \sqrt{\sum_{i=1}^n (A_i \times SE_{C,i})^2} \quad \text{Equation 13}$$

Where:

- A_i = the area of stratum i
- $SE_{C,i}$ = standard error of mean carbon density for stratum i ; and
- n = the total number of strata

Where uncertainty is instead reported for the project-area mean carbon density, the aggregated standard error shall be divided by the total project area.

Where uncertainty components are correlated, covariance shall be considered. Where the relationships among inputs are non-linear or are not suitably represented by analytical error propagation, the simulation approach described in Section 6.5 or another statistically appropriate method shall be used.

The assumptions underlying uncertainty propagation shall be documented.

6.4 Area Uncertainty

Uncertainty in ecosystem extent, project boundaries, and stratum areas shall be assessed where spatial estimates are derived from remote sensing, GIS classification, field mapping, or other spatial methods.

Where a total carbon-stock estimate is obtained by multiplying carbon density by area, and the uncertainty in these two quantities may reasonably be treated as independent, their uncertainties may be propagated as follows:

$$SE_{C,total} = C_{total} \sqrt{\left(\frac{SE_{D_C}}{D_C}\right)^2 + \left(\frac{SE_A}{A}\right)^2}$$

Equation 14

Where:

- C_{total} = estimated total carbon stock;
- D_C = estimated carbon density per unit area;
- A = estimated area;
- SE_{D_C} = uncertainty or standard error associated with carbon density; and
- SE_A = uncertainty or standard error associated with area.

Where the independence assumption is not appropriate, covariance or another suitable propagation method shall be used.

Spatial accuracy assessment, classification validation, positional uncertainty, or other relevant measures shall be documented where applicable.

6.5 Monte Carlo Simulation

Monte Carlo simulation may be used where uncertainty distributions are non-normal, inputs are correlated, estimation models are non-linear, or analytical error propagation is not appropriate.

Monte Carlo analysis shall:

- define the relevant input variables and probability distributions;
- account for correlations among variables where applicable;
- use a sufficient number of iterations to obtain stable estimates of the resulting distribution and confidence bounds; and
- document the assumptions, distributions, number of iterations, and convergence or stability criteria applied.

Monte Carlo simulation may be used at the pool, stratum, or project level depending on the structure of the accounting model.

6.6 Treatment of Uncertainty and Conservativeness

Uncertainty shall be quantified and reported independently of Methodological Level assignment. Methodological Level describes the characteristics and quality of the data and estimation approach; it does not constitute an uncertainty estimate.

This methodology does not prescribe a single universal project-level uncertainty threshold or deduction factor. Where uncertainty exceeds the precision or quality requirements applicable to a particular measurement or accounting component, the project proponent shall, as appropriate:

- improve sampling or measurement effort;
- apply additional calibration or validation;
- use a more representative parameter or estimation method;
- apply a conservative adjustment where permitted; or
- follow the applicable uncertainty-treatment requirements of the PEMSEA certification framework.

Any uncertainty deduction, conservativeness adjustment, or issuance-related discount shall be transparently documented and shall not substitute for compliance with minimum methodological and data-quality requirements.

The project-level de minimis threshold established in Section 10.4 concerns the significance of excluded accounting components and shall not be interpreted as an allowable uncertainty threshold.

6.7 Reporting Requirements

Uncertainty reporting shall identify, as applicable:

- the estimate and associated standard error or standard deviation;
- the confidence interval and confidence level used;
- relative uncertainty or relative error;
- major contributing sources of uncertainty;
- the method used to combine or propagate uncertainty; and
- any conservativeness adjustment or deduction applied.

Uncertainty shall be reported at the level appropriate to the accounting component and, where relevant, at the overall project level.

The confidence level used shall be clearly stated. Where an ecosystem-specific method or certification requirement prescribes a confidence level or precision target, that requirement shall apply.

6.8 QA/QC Procedures

Quality assurance and quality control (QA/QC) procedures shall be systematically applied at all stages of data collection, analysis, and reporting to ensure the accuracy, consistency, and credibility of carbon stock estimates and GHG accounting. General QA/QC procedures applicable to all ecosystems include:

- a. Calibration of instruments used for field and laboratory measurements;
- b. Replication of field measurements and laboratory analyses to detect and quantify variability;
- c. Standardized field protocols and data sheets to minimize procedural errors;
- d. Independent review and validation of data entries, calculations, and spatial analyses;
- e. Regular training and supervision of field and lab personnel to maintain methodological consistency;
- f. Archiving of raw data, calibration records, and analysis reports for traceability.
- g. Verification of formulas, unit conversions, and uncertainty calculations; and
- h. Version control and documentation of changes to models, parameters, spatial datasets, and calculation files.

Ecosystem-specific QA/QC procedures shall be described in Annexes A–C.

7. METHODOLOGICAL LEVELS AND DATA QUALITY

This chapter establishes the Methodological Level system for selecting and documenting data sources, measurement methods, and estimation approaches used in blue carbon accounting.

The system provides a consistent basis for assessing the specificity, representativeness, and methodological rigor of estimates across ecosystems and carbon pools. It accommodates different data availability and technical capacities while encouraging progressive improvement in measurement and monitoring.

The Methodological Levels are informed by established carbon-accounting guidance and data-quality hierarchies but do not correspond directly to IPCC Tier 1, Tier 2, or Tier 3.

Methodological level and uncertainty are related but distinct. A higher methodological level does not automatically demonstrate greater accuracy or lower uncertainty. Uncertainty shall be quantified independently in accordance with Chapter 6.

7.1 Methodological Levels

Three methodological levels are established for assessing the data and methods used to quantify carbon stocks, carbon stock changes, and relevant GHG emissions or removals.

Level 1 – Basic

- Estimation based primarily on published parameters and existing data, supplemented by essential field observations where required.
- Generalized or regionally applicable factors; available ecosystem maps; limited site-specific calibration; documented assumptions and limitations.

Level 2 – Standard

- Estimation incorporating locally representative data and structured measurement procedures.
- Field-based sampling; locally or regionally appropriate parameters; ecosystem stratification; standard laboratory methods; documented calibration and validation.

Level 3 – Advanced

- Estimation supported by detailed site-specific measurements, locally validated models, and enhanced spatial or temporal assessment where relevant.
- Representative site-specific datasets; repeated measurements where needed; model calibration and validation; detailed characterization of spatial or temporal variability; rigorous documentation and QA/QC.

The characteristics above describe general methodological progression. The assignment of a level shall be based on the suitability and quality of the methods and data actually applied, rather than the availability of particular instruments or technologies.

All methodological levels remain subject to the minimum measurement, accounting, and documentation requirements established elsewhere in the methodology and its annexes.

7.2 Application by Carbon Pool and Measurement Category

Methodological levels shall be assigned to the relevant components of project accounting, including ecosystem area or extent, individual carbon pools, and GHG emission or removal estimates.

Different levels may be applied to different components within the same project. For example, a project may use Level 2 methods for aboveground biomass, Level 3 methods for soil organic carbon, and Level 2 methods for ecosystem extent.

Level assignment shall consider the data sources, estimation models, field measurements, and validation procedures supporting each component. The use of a higher-level method for one component shall not automatically raise the methodological level of another component or the project as a whole.

Where different levels are combined within a single estimate, the contribution and limitations of material inputs shall be disclosed.

Ecosystem-specific guidance for method selection and level assignment is provided in Annexes A–C.

7.3 Data Quality, Validation, and Fitness for Purpose

The selection of data sources and estimation methods shall consider their relevance to the target ecosystem, carbon pool, project conditions, and intended accounting purpose.

Preference should be given to locally representative and directly measured data where these are available and appropriate. Regional parameters, published models, and default factors may be used where permitted under the methodology, provided their applicability and limitations are justified.

The evaluation of data and methods shall consider spatial and temporal representativeness, measurement accuracy, model applicability, calibration and validation, and completeness of documentation.

Remote sensing, LiDAR, UAV observations, automated measurements, and other advanced technologies may support higher methodological levels where they provide appropriately validated information for the intended accounting purpose.

The use of advanced technology alone shall not justify assignment to a higher methodological level.

Similarly, direct measurement does not automatically establish greater accuracy if sampling design, calibration, representativeness, or data quality are inadequate.

7.4 Relationship to Uncertainty

Methodological levels describe the approach used to generate an estimate. They do not represent predetermined uncertainty classes.

Higher methodological levels generally involve greater use of site-specific information and validation, which may reduce reliance on generalized assumptions. However, the resulting uncertainty depends on the quality, representativeness, and variability of the underlying data.

Uncertainty shall be quantified and reported for relevant carbon pools, GHG estimates, and spatial area measurements in accordance with Chapter 6.

Level assignment shall not substitute for uncertainty quantification or demonstrate compliance with uncertainty requirements.

The treatment of uncertainty in determining eligible GHG benefits shall follow the relevant quantification requirements from the methodology and the accompanying PEMSEA certification framework.

7.5 Methodological Improvement and Reporting

Project proponents are encouraged to improve methodological quality throughout project implementation and monitoring.

Improvements may include more representative sampling, development of locally appropriate parameters, additional field measurements, improved calibration and validation, repeated observations, or more suitable spatial datasets.

Advancement to a higher methodological level shall be supported by documented improvements in the underlying data and methods. Adoption of new equipment, analytical techniques, or remote-sensing products shall not independently constitute methodological advancement.

Projects shall document the methodological level applied to each relevant accounting component, including the data sources, estimation methods, assumptions, validation procedures, and limitations supporting its assignment.

Methodological levels shall be reported consistently for baseline and project scenarios. Changes in methods or level assignments shall be documented, and their effects on the comparability of estimates across monitoring periods shall be assessed.

Detailed ecosystem-specific examples and method-selection guidance are provided in Annexes A–C.

8. BASELINE SCENARIO

The baseline scenario represents the most plausible conditions and trajectory that would occur in the absence of the proposed project activity. It provides the counterfactual against which project-induced greenhouse gas (GHG) emission reductions and removals are quantified.

The baseline shall reflect relevant changes in ecosystem condition, land or marine use, carbon stocks, and GHG emissions or removals over the applicable assessment period. Establishing a credible and appropriately conservative baseline is essential for quantifying net GHG benefits and demonstrating additionality in accordance with Section 3.4.

8.1 Baseline Determination Framework

Baseline determination shall identify the most plausible condition and trajectory of the project area in the absence of the proposed project activity. Baseline determination and additionality assessment are related but distinct. This section establishes the counterfactual scenario against which project GHG benefits are quantified, while additionality shall be demonstrated separately in accordance with Section 3.4.

The baseline shall be supported by evidence appropriate to the project type and may consider:

- existing and historical land or marine use and ecosystem condition;
- observed trends in ecosystem extent, degradation, recovery, management, or conversion;
- continuation of existing management practices or productive activities;
- legally permitted, planned, or reasonably foreseeable land- or marine-use changes;
- natural regeneration, succession, erosion, degradation, or other ecological processes expected without project intervention; and
- relevant spatial, temporal, socioeconomic, regulatory, and management information supporting the plausibility of the identified trajectory.

Where more than one plausible baseline scenario exists, the selected scenario shall be justified using transparent evidence and assumptions. The baseline shall not assume implementation of the proposed project activity or its associated carbon benefits.

Baseline assumptions, data sources, and the rationale for scenario selection shall be documented sufficiently to permit independent review.

8.2 Baseline Quantification

Baseline carbon stocks, carbon-stock changes, and relevant GHG emissions or removals shall be quantified for the carbon pools and GHG sources or sinks applicable to the baseline scenario. Pool inclusion and exclusion shall follow Section 4.3 and the relevant ecosystem-specific annexes.

Baseline estimates shall use the accounting approaches described in Chapter 5, the uncertainty procedures in Chapter 6, and the Methodological Level framework in Chapter 7. Depending on available data and the nature of the baseline trajectory, carbon-stock change may be estimated using:

- **Stock-Difference Method:** comparison of carbon stocks measured or reconstructed at two or more comparable time points; or
- **Gain-Loss Method:** estimation of carbon gains and losses using applicable activity data, measured or published rates, emission factors, or other justified parameters.

Baseline and project-scenario estimates shall use consistent or demonstrably comparable carbon-pool definitions, spatial boundaries, stratification, measurement depths, parameters, and estimation procedures.

A value of zero may be assigned to a specific carbon pool, stock-change component, or GHG source only where its absence or negligible change is demonstrated, or where such treatment is explicitly prescribed by the applicable ecosystem-specific method. Assignment of a zero value to one component shall not imply that other existing carbon pools or GHG sources are zero.

8.3 Baseline Projection and Reassessment

Where baseline carbon stocks, ecosystem extent, management conditions, or GHG emissions or removals are expected to change over time, the baseline shall be represented as a dynamic trajectory over the applicable assessment period.

Baseline projections may use, where appropriate:

- observed historical trends in ecosystem extent, land or marine use, vegetation condition, or carbon stocks;
- site-specific or locally representative ecological and management information;
- applicable models or published ecological information; and
- relevant environmental drivers, including sea-level rise, erosion, sediment dynamics, climate variability, or land-use change.

Projection methods, assumptions, and input data shall be documented and justified.

The baseline scenario shall remain valid for a maximum period of 10 years before formal reassessment. Reassessment shall also be undertaken earlier where material changes occur in project boundaries, land or marine use, ecosystem condition, management practices, or other factors that materially affect the validity of the baseline. Where an ecosystem-specific provision requires a shorter reassessment interval, the shorter interval shall apply.

Baseline reassessment shall use updated information available at the time of reassessment and shall be documented in accordance with the monitoring and verification requirements of this methodology.

8.4 Use of Data Sources and Default Values

Data used for baseline quantification shall be selected according to their relevance, representativeness, and methodological quality. Where available and appropriate, the following hierarchy should be applied:

1. Site-specific measured data or locally calibrated and validated models;
2. Locally or regionally representative data, including national inventories, peer-reviewed studies, and regionally validated parameters; and
3. Applicable published default values, including internationally recognized default factors where more representative information is unavailable.

Where data from a lower level of geographic or ecological representativeness are used, their applicability to the project conditions shall be justified.

All data sources and default values shall:

- be clearly referenced and documented;
- be appropriate to the ecosystem, geographic setting, carbon pool, and management condition;
- identify relevant limitations and uncertainty; and
- be applied conservatively where uncertainty or lack of representativeness could materially overstate GHG benefits.

Where proxy indicators such as salinity, elevation, vegetation condition, or land-use history are used, the relationship between the proxy and the parameter being estimated shall be documented and justified.

8.5 Stratification and Methodological Level Assignment

Baseline estimates shall apply the stratification principles established in Section 4.4 and the Methodological Level principles established in Chapter 7. Each relevant accounting component, including ecosystem extent, carbon pools, and GHG estimates, shall be assigned a methodological level based on the underlying data and estimation approach.

Level assignments and associated methods shall be documented and justified. Baseline and project-scenario estimates shall use consistent or demonstrably comparable approaches. Uncertainty shall be assessed independently in accordance with Chapter 6.

8.6 QA/QC and Uncertainty Management

All baseline estimates shall be subject to the QA/QC and uncertainty procedures established in Chapter 6. Sources of uncertainty shall be identified, quantified where practicable, and propagated across relevant pools, strata, activity data, and spatial estimates.

Where uncertainty could materially affect the estimated net GHG benefit, projects shall apply the conservativeness and uncertainty-treatment procedures specified in Chapter 6 and the relevant ecosystem-specific annex.

Baseline projections, data sources, assumptions, and subsequent revisions shall be transparently documented to support independent review and verification. Changes to baseline assumptions during the project period shall be justified and addressed through the baseline reassessment procedures in Section 8.3.

9. PROJECT SCENARIO AND QUANTIFICATION

The project scenario represents the ecological conditions, land or marine use, and management practices resulting from implementation of the project activity. Project-scenario accounting shall quantify changes in relevant carbon pools and greenhouse gas emissions or removals relative to the baseline scenario.

Project GHG benefits may result from increased carbon removals, reduced GHG emissions, avoided carbon-stock losses, or a combination of these effects. Carbon-stock changes, GHG emissions and removals, and leakage shall be integrated into the net GHG benefit calculation in Section 9.6.

Baseline and project-scenario accounting shall use consistent or demonstrably comparable spatial boundaries, carbon-pool definitions, measurement depths, data sources, and estimation procedures so that calculated differences reflect project effects rather than methodological differences.

9.1 Project Area Stratification

Project areas shall be stratified based on biophysical and management variables that materially influence carbon stocks, carbon-stock changes, or GHG emissions and removals, such as vegetation type, salinity, hydrology, sediment characteristics, or intervention type. Stratification shall improve representativeness and support efficient sampling and accounting.

Project-scenario strata may differ from baseline strata where project activities alter vegetation, hydrological conditions, ecosystem state, or management. Where strata differ between scenarios, their spatial correspondence and areas shall be documented so that changes resulting from reclassification are not incorrectly interpreted as changes in carbon stocks or GHG benefits.

All strata shall be clearly delineated and documented using appropriate spatial data. Ecosystem-specific stratification guidance is provided in Annexes A–C.

9.2 Carbon Stock Estimation under the Project Scenario

Project-scenario carbon stocks and carbon-stock changes shall be estimated in accordance with Chapters 5 and 6 and the applicable ecosystem-specific methods in Annexes A–C.

Carbon pools shall be included or excluded in accordance with Section 4.3.3 and the relevant ecosystem-specific annex. Each included accounting component shall use methods appropriate to its assigned Methodological Level under Chapter 7.

Methodological Level assignments, data sources, estimation methods, calibration and validation procedures, and relevant assumptions shall be documented for each accounting component. Different methodological levels may be applied to different carbon pools or components within the same project.

Baseline and project-scenario estimates shall use consistent or demonstrably comparable methods. Where methods or data sources differ, the project proponent shall demonstrate that the resulting estimates remain comparable and that the change does not introduce a systematic bias in the estimated project GHG benefit.

9.3 Carbon Stock Change and Sequestration Rate Estimation

Carbon-stock changes and sequestration rates may be estimated using the Stock-Difference or Gain–Loss Method, depending on the carbon pool, available data, and monitoring design.

- **Stock-Difference Method:** Carbon-stock change is estimated by comparing comparable stock estimates at two or more points in time. Where measurements span multiple years, the observed stock change may be annualized by dividing the change by the elapsed measurement interval.
- **Gain–Loss Method:** Carbon-stock change is estimated from the balance of relevant carbon gains and losses using measured or appropriately justified rates, activity data, and estimation parameters.

Different approaches may be applied to different carbon pools or accounting components within the same project, provided that their application is documented and does not result in double counting.

Measurements such as sediment accretion, surface-elevation change, radiometric dating, litterfall, biomass growth observations, and remote sensing may provide data or estimation inputs to the applicable accounting approach. Their use does not constitute a separate ecosystem-level

accounting method and does not, by itself, determine the Methodological Level of the resulting estimate.

Carbon-stock changes may be reported in $\text{Mg C ha}^{-1} \text{ yr}^{-1}$ or other appropriate carbon units for intermediate calculations. Quantities contributing to the final net GHG benefit shall be converted to tCO_2e in accordance with Section 9.6.

9.4 GHG Emissions and Avoided Emissions

Project accounting shall include GHG emission sources that are materially affected by project activities or differ between the baseline and project scenarios. Depending on the ecosystem and project activity, relevant gases may include CO_2 , CH_4 , and N_2O .

Applicability shall be determined according to the ecological conditions and activities affecting the emission source, including hydrological change, salinity, soil disturbance, nutrient inputs, fertilizer or wastewater inputs, and other relevant management practices. Applicability shall not be determined by Methodological Level.

Where a GHG source is demonstrated to remain unchanged between the baseline and project scenarios, it may be omitted from the net calculation provided that the omission is documented and does not overstate the project GHG benefit.

A GHG source may also be assigned a zero value or excluded where such treatment is explicitly supported by the relevant ecosystem-specific provision or applicable estimation method. Any environmental threshold or condition used to justify such treatment shall be documented.

A GHG source may be excluded as de minimis only where it forms part of the cumulative project-level exclusions assessed in accordance with Section 10.4, and the combined contribution of all excluded carbon pools, project GHG sources, and leakage sources remains below the applicable de minimis threshold. A source shall not be excluded where its omission would systematically overestimate the project GHG benefit.

GHG emissions may be estimated using direct measurements, locally representative emission factors, validated models, or applicable published defaults, consistent with the data-quality and Methodological Level principles in Chapter 7. Uncertainty shall be assessed in accordance with Chapter 6.

Non- CO_2 GHG emissions shall be converted to CO_2 equivalents using 100-year Global Warming Potential values adopted by the applicable national GHG inventory or certification framework. The GWP source and values applied shall be documented.

9.5 Leakage Assessment

Potential leakage resulting from project activities shall be identified, assessed, quantified where applicable, and deducted from the project GHG benefit in accordance with Chapter 10.

Where leakage is determined to be negligible or zero, the basis for that determination shall be documented using the applicability and materiality procedures in Chapter 10.

9.6 Net GHG Benefit Calculation

The net GHG benefit represents the difference between the net GHG balance under the baseline scenario and the net GHG balance under the project scenario, after deduction of applicable leakage.

For each reporting year t :

$$\begin{aligned} \text{Net GHG Benefit}_t &= GHG(\text{Baseline}, t) - GHG(\text{Project}, t) \\ &\quad - GHG(\text{Leakage}, t) \end{aligned} \quad \text{Equation 15}$$

where:

$GHG(\text{Baseline}, t)$ = net baseline GHG emissions and removals;

$GHG(\text{Project}, t)$ = net project-scenario GHG emissions and removals; and

$GHG(\text{Leakage}, t)$ = applicable net GHG emissions attributable to leakage.

For purposes of this calculation, emissions shall be treated as positive contributions to the scenario GHG balance and removals as negative contributions. A positive value of the resulting Net GHG Benefit therefore represents a net atmospheric benefit relative to the baseline.

Avoided emissions shall be represented through the difference between baseline and project-scenario emissions and shall not be added separately where they are already captured in that difference.

Carbon-stock changes measured over multi-year intervals shall be annualized where required for annual accounting. Net GHG benefits shall be calculated and reported in tCO₂e, and annual values may be aggregated over the applicable monitoring or verification period.

Project GHG benefits may accrue from the documented project start date. Eligibility for certification or credit issuance shall be based on ex-post verification in accordance with the applicable certification requirements.

Uncertainty shall be quantified and reported in accordance with Chapter 6 and shall be treated separately from Methodological Level assignment.

9.7 Documentation and Verification

The project proponent shall maintain records sufficient to reproduce and independently review project-scenario quantification. Documentation shall include the methods, equations, activity data, carbon-stock and GHG estimates, data sources, Methodological Level assignments, calibration and validation procedures, assumptions, GWP values, exclusions, leakage estimates, uncertainty assessments, and QA/QC procedures applied.

The basis for determining the applicability or exclusion of carbon pools and GHG sources shall be documented, including any de minimis calculations or ecosystem-specific provisions used.

Baseline and project-scenario estimates shall be reviewed for methodological consistency and comparability. Changes in methods, data sources, stratification, or Methodological Level assignments between monitoring periods shall be documented and their effects on estimate comparability and uncertainty assessed.

10. LEAKAGE

10.1 Definition and Scope

Leakage is the net increase in greenhouse gas emissions or decrease in removals occurring outside the project boundary that is attributable to project activities.

Leakage shall be assessed where project activities may displace land or resource use, alter market-mediated production or extraction, or cause hydrological or ecological effects beyond the project boundary.

Quantified leakage shall be deducted from the project GHG benefit in accordance with Section 9.6. Reductions in emissions or increases in removals occurring outside the project boundary shall not be credited as negative leakage.

10.2 Applicability

Leakage applicability shall be assessed according to the project activity, pre-project land or resource use, and the potential causal pathways through which project implementation could affect areas outside the project boundary.

Leakage may be assigned a value of zero only where:

- the relevant leakage pathway is demonstrably not applicable to the project activity;
- project eligibility or design conditions explicitly establish that no displacement or off-site effect is expected;
- applicable regulatory or methodological provisions prescribe zero leakage under defined conditions; or
- verifiable evidence demonstrates that the project does not cause a material increase in emissions or decrease in removals outside the project boundary.

The basis for assigning zero leakage shall be documented. General statements concerning legal protection, project intent, or the presence of mitigation measures shall not, by themselves, be sufficient to demonstrate zero leakage.

10.3 Types of Leakage and Estimation Approaches

The relevance of each leakage category shall be determined according to the project activity and ecosystem context. Not all leakage categories apply to all project types.

10.3.1 Activity-Shifting Leakage

Activity-shifting leakage occurs where pre-project land use, resource extraction, aquaculture, agriculture, harvesting, or other activities displaced by the project are transferred outside the project boundary and result in increased GHG emissions or reduced removals.

Where applicable, assessment may use spatial land-use change analysis, activity or production data, stakeholder or household information, and appropriate emission or carbon-stock factors.

10.3.2 Market-Effects Leakage

Market-effects leakage may occur where a project materially reduces the supply of a commercially traded product and induces increased production or extraction elsewhere.

Market leakage is generally more relevant to conservation or avoided-conversion activities involving commercially significant products than to restoration activities on abandoned or degraded sites. Its applicability shall therefore be demonstrated before quantification is required.

Where applicable, estimation shall use appropriate commodity, production, market, and emission data or validated activity-specific factors.

10.3.3 Ecological Leakage

Ecological leakage occurs where project-induced hydrological, geomorphological, or ecological changes extend beyond the project boundary and cause increased GHG emissions, carbon-stock losses, or reduced removals.

Potential pathways may include changes in water-table depth, tidal exchange, inundation, salinity, erosion, sediment transport, or vegetation condition in adjacent areas.

Where such effects are plausible, assessment shall use appropriate hydrological, spatial, field, or other scientifically justified evidence.

10.4 Significance Testing and Materiality

Leakage sources shall be assessed together with other excluded carbon pools and GHG emission sources under the project-level de minimis procedure.

The combined contribution of all excluded carbon pools, project GHG sources, and leakage sources may be treated as de minimis only where it is demonstrated to represent less than 5% of the estimated total net GHG benefit before deduction of leakage.

Leakage may also be excluded where a zero value or exclusion is explicitly prescribed under an applicable ecosystem-specific or activity-specific provision and the stated applicability conditions are satisfied.

All exclusions and significance assessments shall be documented and reassessed during monitoring where the underlying conditions may change.

10.5 Quantification Methods

Leakage shall be quantified using methods appropriate to the identified leakage pathway and the type of activity displaced or affected.

Depending on the leakage source, estimation may use:

- spatial analysis of land- or ecosystem-use change;
- changes in production, extraction, or other activity data;
- carbon-stock or GHG emission factors;
- field measurements or monitoring of affected areas;
- hydrological or ecological models; or
- activity-specific leakage factors supported by applicable data or established methodology.

Where published factors or models are used, their applicability and representativeness shall be justified. Leakage estimates shall follow the data-quality, uncertainty, and Methodological Level principles established in Chapters 6 and 7, as applicable.

10.6 Leakage Deduction and Net GHG Benefit Calculation

Total leakage emissions for reporting period t shall equal the sum of applicable quantified leakage sources:

$$\text{GHG}_{\text{Leakage},t} = \sum \text{GHG}_{\text{Leakage},i,t} \quad \text{Equation 16}$$

Leakage shall be expressed in tCO₂e and deducted from the baseline–project GHG difference in accordance with Section 9.6.

Where calculated leakage is less than zero, leakage shall be set to zero:

$$\text{GHG}_{\text{Leakage},t} \geq 0 \quad \text{Equation 17}$$

Activity-specific leakage factors or adjustment factors may be used only where their derivation, applicability, and source are documented and appropriate to the relevant leakage pathway. Generic percentage deductions shall not be applied in the absence of such justification.

10.7 Monitoring and Reassessment Requirements

Leakage applicability, assumptions, and quantified parameters shall be reviewed at each monitoring or verification event.

Leakage shall also be reassessed where material changes occur in:

- project design or boundaries;
- pre-project or displaced land/resource uses;
- surrounding land-use pressure;
- commodity or market conditions relevant to market leakage;
- hydrological or ecological conditions affecting adjacent areas; or
- leakage-mitigation activities.

Monitoring frequency and data requirements shall be specified in the project Monitoring Plan and supported by traceable data.

10.8 Reporting and Documentation

Project documentation shall:

- identify potential leakage pathways and their applicability;
- document the basis for any zero-leakage determination or exclusion;
- describe estimation methods, parameters, assumptions, and data sources;
- report quantified leakage and associated uncertainty;
- document changes identified during monitoring and reassessment; and
- retain supporting spatial, field, activity, and calculation records sufficient for independent review and verification.

10.9 Leakage Mitigation Measures

Projects should implement appropriate measures to prevent or reduce identified leakage risks. Depending on the project context, measures may include:

- participatory land- and resource-use planning;
- alternative or supplementary livelihood measures;
- maintenance of pre-project resource or service levels where appropriate;
- establishment of leakage-management or co-managed areas;
- hydrological safeguards or buffer areas; and
- alignment with relevant land-use, coastal-management, and conservation plans.

Leakage-mitigation measures shall not, by their implementation alone, justify assigning leakage a value of zero. Any reduction in quantified leakage attributed to mitigation measures shall be supported by evidence demonstrating their effectiveness.

GHG emissions caused by leakage-mitigation activities shall be included in project or leakage accounting where applicable and shall not be omitted where doing so would materially overstate the project GHG benefit.

11. PERMANENCE AND RISK MANAGEMENT

11.1 Permanence and Non-Permanence Risk

Permanence refers to the continued retention of carbon stocks or other climate benefits whose integrity depends on maintaining carbon stored within the project system. Blue carbon ecosystems may retain substantial quantities of carbon in living biomass and soils; however, these stocks may be affected by natural disturbance, land- or marine-use change, hydrological alteration, erosion, management failure, or other events.

Projects shall identify and manage non-permanence risks throughout the applicable project and crediting period. Where the applicable certification framework establishes an additional permanence, monitoring, or liability period, those requirements shall also apply.

Non-permanence treatment shall apply to credited GHG benefits that depend on the continued storage of carbon. Emission reductions that have already occurred during a completed reporting period and do not depend on continued carbon storage shall not be treated as physical carbon-stock reversals.

Permanence risk shall be reassessed at each verification event and following any major disturbance or material change that could affect credited carbon stocks. Where verification intervals exceed five years, a documented risk reassessment shall be undertaken at least every five years.

11.2 Risk Identification and Assessment

Projects shall conduct and document a non-permanence risk assessment covering risks that could cause material loss of credited carbon stocks or impair the continued effectiveness of project activities.

Relevant risks may include:

a. Natural and Environmental Risks:

- typhoons, storm surges, flooding, drought, and sea-level rise;
- erosion, sediment loss, shoreline change, and hydrological alteration;
- wildfire, pests, disease, vegetation dieback, and other ecological disturbances.

b. Anthropogenic and Management Risks:

- logging, harvesting, land or marine conversion, and unregulated aquaculture;
- dredging, infrastructure development, drainage, or other hydrological modification;
- inadequate maintenance, restoration failure, or unsustainable resource use.

c. Governance and Socioeconomic Risks:

- unclear tenure or resource-use rights;
- weak enforcement or institutional capacity;
- stakeholder conflict or inadequate community engagement;
- financial or management conditions that may affect long-term project implementation.

Risk significance shall be evaluated using the likelihood of occurrence and the potential magnitude of carbon-stock loss. Historical disturbances, site exposure, ecosystem condition, project design, and existing management safeguards shall be considered.

The risk assessment method, evidence used, assumptions, and resulting risk classification shall be documented and updated in accordance with Section 11.1.

11.3 Risk Mitigation and Monitoring

Project proponents shall identify and implement measures appropriate to the material risks identified in Section 11.2. Measures may include:

- hydrological and ecological design measures that reduce exposure to disturbance;
- protection or restoration of natural buffers and sediment processes;
- use of locally appropriate species or natural regeneration approaches;
- strengthened tenure, governance, and enforcement arrangements;
- stakeholder engagement and resource-use agreements;
- contingency planning and financial provisions for restoration or remedial action; and
- monitoring of indicators associated with identified permanence risks.

Risk mitigation measures shall be incorporated into project monitoring and management. Their implementation alone shall not automatically reduce the assessed non-permanence risk. Any reduction in risk classification or related certification requirement shall be supported by evidence that the measure materially reduces the likelihood or consequence of carbon-stock loss.

Relevant monitoring indicators may include vegetation condition, mortality, ecosystem extent, shoreline position, hydrological conditions, erosion, salinity, disturbance occurrence, or other parameters appropriate to the identified risk.

11.4 Reversals and Non-Permanence Treatment

A reversal occurs where a previously credited GHG benefit that depends on continued carbon storage is subsequently lost through a reduction in the relevant project carbon stock.

Potential reversals may result from natural or anthropogenic disturbances, including severe storms, erosion, fire, vegetation mortality, hydrological change, harvesting, land conversion, or other events affecting credited carbon stocks.

Following a material disturbance, the project proponent shall:

- identify and map the affected area;
- determine whether project strata or boundaries require revision;
- remeasure or otherwise quantify affected carbon stocks using appropriate methods;
- estimate the magnitude of any loss of previously credited carbon;
- document whether the event was intentional or unintentional, where relevant; and
- report the event and resulting carbon-stock change at the next verification, or earlier where required by the applicable certification framework.

Where a permanent change in land or ecosystem condition renders an affected area no longer eligible for project accounting, the area shall be removed or reclassified for future accounting as appropriate.

The mechanism used to address a verified reversal—including buffer cancellation, withholding or deduction of future GHG benefits, replacement of previously issued units, or another approved risk-management mechanism—shall be determined by the applicable PEMSEA certification framework.

The methodology itself does not prescribe a single buffer-reserve percentage or compensation mechanism.

12. MONITORING AND REPORTING

Effective monitoring and reporting are essential for ensuring the environmental integrity, transparency, and credibility of blue carbon projects.

12.1 Monitoring Plan Design

Each project shall establish and maintain a Monitoring Plan covering the parameters, methods, schedules, responsibilities, and data-management procedures required to quantify and document project GHG benefits over time.

The Monitoring Plan shall:

- identify the carbon pools, GHG sources, activity data, spatial variables, and relevant environmental or management indicators to be monitored;
- define the sampling design, monitoring locations, strata, and methods applicable to each parameter;
- specify the frequency and timing of monitoring for each parameter;
- describe field, laboratory, remote-sensing, and other analytical methods to be applied;
- specify QA/QC procedures, calibration requirements, data handling, and record-keeping procedures;
- identify responsible personnel or organizations; and
- identify procedures for responding to disturbances, boundary changes, data gaps, or other conditions requiring reassessment.

The Monitoring Plan shall be reviewed periodically and updated where changes in project design, monitoring conditions, approved methodological requirements, or material ecological or operational conditions affect the continued suitability of the monitoring approach. Changes shall be documented and shall preserve comparability with previous monitoring periods where practicable.

12.2 Monitoring Strategy and Frequency

Monitoring frequencies shall be established according to the carbon pool, GHG source, environmental parameter, expected rate of change, seasonal variability, and purpose of the measurement.

Monitoring and verification are distinct processes. Field and environmental parameters shall be measured according to their applicable technical monitoring schedules and do not need to be remeasured solely because a verification event occurs, unless required by the applicable method or triggered by a material change or disturbance.

Parameter-specific monitoring frequencies shall follow the relevant ecosystem-specific and environmental annexes:

- Annex A for mangrove carbon pools and associated measurements;
- Annex B for seagrass carbon pools and associated measurements;
- Annex C for salt marsh carbon pools and associated measurements; and
- Annex E for environmental parameters influencing blue carbon ecosystems.

Monitoring may be continuous, seasonal, annual, periodic, or event-based depending on the parameter. Parameters exhibiting strong seasonal or short-term variability, including certain GHG fluxes, hydrological variables, salinity, and water levels, shall be monitored at a frequency sufficient to characterize the relevant temporal variability.

Carbon-stock changes measured over multi-year intervals may be annualized in accordance with the applicable accounting method. Monitoring frequencies shall not be shortened or extended solely to align with verification schedules where doing so would reduce the representativeness or reliability of the estimate.

Verification frequency shall be determined separately in accordance with Chapter 13 and the applicable certification framework.

12.3 Parameters and Indicators

Monitoring shall include the parameters necessary to quantify the baseline and project scenarios, track implementation, identify relevant risks and disturbances, and support verification.

Depending on project type and ecosystem, monitored parameters may include:

- Carbon stocks and stock-change parameters — aboveground biomass, belowground biomass, soil organic carbon, and other included carbon pools;
- GHG sources and fluxes — CO₂, CH₄, and N₂O where applicable under the project activity and environmental conditions;
- Spatial and activity data — ecosystem extent, project boundaries, strata, land or marine use, restoration extent, vegetation establishment, management activities, and disturbance areas;

- Environmental parameters — salinity, water level, inundation, sediment accretion or elevation change, erosion, and other variables required to interpret or estimate carbon dynamics; and
- Project-performance and risk indicators — survival, regeneration, vegetation condition, infrastructure condition, disturbance occurrence, hydrological performance, or other indicators relevant to project implementation and permanence.

Only parameters relevant to the applicable accounting methods, monitoring objectives, and project conditions need to be monitored. Detailed ecosystem-specific measurement procedures are provided in Annexes A–C, while environmental monitoring guidance is provided in Annex E.

12.4 Data Management and QA/QC

Projects shall implement data-management and QA/QC procedures sufficient to ensure the traceability, integrity, consistency, and reproducibility of monitoring results.

Requirements shall include, as applicable:

- standardized field and laboratory data-recording procedures;
- retention of raw and processed monitoring data;
- documented instrument calibration and maintenance;
- spatial datasets, project boundaries, strata, and associated metadata;
- laboratory analytical records and calculation files;
- photographic or other supporting field documentation;
- internal data checks and independent review of calculations;
- version control for datasets, equations, models, and spatial products; and
- clear assignment of responsibilities for data collection, entry, processing, review, and approval.

Monitoring records shall be retained throughout the operational and crediting life of the project and for at least two years following the end of the crediting period or final verification, whichever is later. Longer retention periods shall apply where required by applicable national regulations or certification requirements.

QA/QC procedures shall follow Chapter 6 and the applicable ecosystem-specific annexes and shall allow monitoring results to be independently reproduced and verified.

12.5 Reassessment Triggers

The Monitoring Plan, monitoring parameters, strata, and applicable estimation assumptions shall be reassessed where information becomes available indicating that the existing monitoring approach may no longer adequately represent project conditions.

Reassessment shall be undertaken, as applicable:

- at verification events where monitoring assumptions or project conditions require review;
- following significant natural or anthropogenic disturbances, including storms, erosion, fire, vegetation dieback, or other material carbon-stock losses;
- following material changes in project boundaries, strata, land or marine use, or project activities;
- where observed project implementation materially differs from the original project design;
- where leakage, permanence risk, or baseline conditions require reassessment under Chapters 8, 10, or 11; and
- where approved methodological or technical changes materially affect the methods or parameters used by the project.

Reassessment shall not replace routine parameter-specific monitoring. Where a disturbance or material change affects project strata or boundaries, the affected area shall be identified and re-stratified, reclassified, or removed from future accounting as appropriate.

Changes to monitoring methods shall be documented, including their rationale and any implications for comparability, uncertainty, and previously reported estimates.

12.6 Monitoring Report and Reporting Requirements

A Monitoring Report shall be prepared for each applicable verification period and shall provide sufficient information to reproduce and independently assess the reported GHG benefits.

At minimum, the Monitoring Report shall document:

- project identification, reporting period, project boundaries, and relevant spatial data;
- project activities implemented during the monitoring period;
- current ecosystem extent, strata, and any boundary or stratification changes;
- carbon pools, GHG sources, and leakage sources included or excluded from accounting, including the basis for exclusions;
- monitoring methods, sampling design, measurement dates, and data sources;

- field, laboratory, remote-sensing, and spatial-analysis procedures;
- Methodological Level assignments and any changes in methods or data quality;
- carbon-stock changes, GHG emissions and removals, and leakage estimates;
- annualized and monitoring-period net GHG benefits in tCO₂e;
- uncertainty estimates and any applicable conservativeness adjustments;
- QA/QC procedures and identified data limitations;
- disturbances, reversals, deviations from project design, and corrective or adaptive-management actions; and
- changes from previous monitoring periods and their implications for estimate comparability.

Supporting calculations, spatial datasets, field and laboratory records, and other underlying evidence shall be retained and made available for verification.

A standardized Monitoring Report template or summary reporting table may be provided as an accompanying implementation tool or appendix to support consistent reporting across projects.

13. VALIDATION, VERIFICATION, AND CERTIFICATION LINKAGE

Validation and verification provide independent assessment of whether a project is designed, implemented, monitored, and quantified in accordance with this methodology. Validation focuses primarily on project design, eligibility, baseline and additionality, proposed accounting methods, and the Monitoring Plan, while verification assesses monitored GHG benefits and compliance during completed monitoring periods.

This chapter establishes the methodological information and checks required to support validation and verification. Requirements concerning verifier accreditation, certification decisions, registry operation, credit issuance, serial numbering, appeals, and other program-administration functions shall be governed by the accompanying PEMSEA certification framework.

13.1 Validation and Verification Functions

Validation and verification shall be conducted independently of project development and project GHG quantification.

Validation shall assess, as applicable:

- project eligibility and applicability of this methodology;
- project boundaries, tenure, resource-use rights, and avoidance of overlapping carbon claims;
- baseline scenario determination and additionality;
- selection of carbon pools, GHG sources, leakage pathways, and exclusions;
- proposed stratification, accounting methods, and Methodological Level assignments;
- ex-ante estimates and key assumptions;
- monitoring design, sampling strategy, and QA/QC procedures; and
- conformity with relevant environmental, social, and methodological safeguards.

Verification shall assess, as applicable:

- implementation of the approved project and Monitoring Plan;
- current project boundaries, strata, and any changes since validation or the previous verification;

- monitored carbon stocks, carbon-stock changes, GHG emissions and removals, and activity data;
- leakage, reversals, disturbances, and applicable reassessments;
- sampling design, field and laboratory procedures, remote-sensing and spatial analyses, and QA/QC records;
- calculation of baseline and project GHG balances and net GHG benefits;
- uncertainty assessment, exclusions, and any applicable conservativeness adjustments; and
- consistency and comparability of methods and data across monitoring periods.

Validation and verification bodies shall meet the independence, competence, accreditation, and conflict-of-interest requirements established by the applicable certification framework.

13.2 Verification Process and Criteria

Verification shall be based on the Monitoring Report and supporting evidence required under Chapter 12. Verification frequency shall be determined by the applicable certification framework and shall remain distinct from parameter-specific monitoring frequencies.

Verification shall assess whether:

- the project continues to meet the applicable requirements of this methodology;
- project boundaries, strata, carbon pools, GHG sources, and leakage pathways are correctly represented;
- monitoring data are complete, traceable, and supported by appropriate QA/QC;
- estimation methods, equations, parameters, and Methodological Level assignments are appropriately applied and documented;
- baseline and project-scenario estimates remain methodologically consistent or demonstrably comparable;
- exclusions and de minimis determinations comply with the applicable methodological requirements;
- uncertainty has been calculated and reported in accordance with Chapter 6;
- disturbances, reversals, boundary changes, leakage, and reassessment triggers have been appropriately addressed; and
- reported net GHG benefits can be reproduced from the underlying data and calculations.

Where methods, data sources, stratification, or Methodological Level assignments change between monitoring periods, the project proponent shall document the reason for the change and assess its effect on comparability, uncertainty, and reported GHG benefits.

Methodological changes shall not automatically invalidate previously verified results. The applicability of revised methodology versions to ongoing projects shall be determined in accordance with the versioning and transition rules of the certification framework.

Where the verifier identifies errors, omissions, inconsistencies, or other non-conformities, the project proponent shall address the findings through corrective action, clarification, additional analysis, or re-monitoring as appropriate before a positive verification conclusion is issued.

Verification materiality thresholds, verification opinions, and procedures for unresolved findings or appeals shall be established by the certification framework.

13.3 Certification and Crediting Interface

Successful verification shall result in a documented determination of the verified GHG benefit for the applicable monitoring period.

The verification package shall include, at minimum:

- project identification and applicable project boundaries;
- the verified monitoring period;
- verified baseline and project-scenario GHG estimates;
- quantified leakage;
- applicable uncertainty or conservativeness adjustments;
- treatment of non-permanence or reversal risk, where relevant;
- the resulting verified net GHG benefit in tCO₂e; and
- the verifier's conclusion or verification statement.

The verified results shall provide the technical basis for subsequent certification or crediting decisions under the accompanying PEMSEA certification framework.

Requirements concerning eligible credit volume, non-permanence deductions or buffer mechanisms, registry operation, issuance, serial numbering, transfer, retirement, cancellation, and other administrative functions are outside the scope of this technical methodology and shall be established by the certification framework.

14. ANNEXES

Annexes A–E are issued as accompanying documents and form part of this methodology.

- Annex A: Mangrove Ecosystems – Carbon Accounting Methods
- Annex B: Seagrass Ecosystems – Carbon Accounting Methods
- Annex C: Salt Marsh Ecosystems – Carbon Accounting Methods
- Annex D: Blue Carbon Ecosystems Mapping
- Annex E: Monitoring Environmental Parameters Influencing Blue Carbon Ecosystems

REFERENCES

- Al-Amin, A., Ridwan, M., & Yonvithner. (Eds.). (2023). *Blue Carbon Accounting: Guide-Training*. PKSPL IPB University.
- Howard, J., Hoyt, S., Isensee, K., Pidgeon, E., & Telszewski, M. (Eds.). (2014). *Coastal Blue Carbon: Methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows*. Conservation International, UNESCO, IUCN.
<http://thebluecarboninitiative.org/manual/>
- IPCC. (2006). *2006 IPCC guidelines for national greenhouse gas inventories*.
- IPCC. (2014). *2013 supplement to the 2006 IPCC guidelines for national greenhouse gas inventories: Wetlands*.
- Japan Blue Economy Association. (2023). *J Blue Credit Guideline (Version 2.3)*.
<https://www.blueeconomy.jp/credit/>
- Kauffman, J. B., & Donato, D. C. (2012). *Protocols for the measurement, monitoring and reporting of structure, biomass and carbon stocks in mangrove forests (Working Paper 86)*. CIFOR.
- Ministry of Ecology and Environment of the People's Republic of China. (2023). *Greenhouse gas voluntary emission reduction project methodology: Mangrove creation (CCER-14-002-V01)*.
- Ministry of Natural Resources of the People's Republic of China, Department of Marine Early Warning and Monitoring. (2023). *Technical regulation on accounting and monitoring of carbon sinks in mangrove ecosystems (Trial)*. Ministry of Natural Resources.
- Ministry of Natural Resources of the People's Republic of China, Department of Marine Early Warning and Monitoring. (2023). *Technical regulation on accounting and monitoring of carbon sinks in coastal salt marsh ecosystems (Trial)*. Ministry of Natural Resources.
- Ministry of Natural Resources of the People's Republic of China, Department of Marine Early Warning and Monitoring. (2023). *Technical regulation on accounting and monitoring of carbon sinks in seagrass bed ecosystems (Trial)*. Ministry of Natural Resources.
- Ministry of Natural Resources of the People's Republic of China. (2021). *Estimation method of maricultural seaweed and bivalve carbon sink—Carbon stock variation method (HY/T 0305-2021)*. China Standard Press.
- Nakaoka, M., Herrera, E., Suwa, R., Quevedo, J. M. D., Adi, N. S., Ati, R. N. A., ... Ray, R. (2023). *Core and Network System (CNS) Monitoring Guidelines for Blue Carbon Ecosystems*. JST-JICA SATREPS BlueCARES program. <https://www.bluecaresproject.upd.edu.ph>

National Standardization Agency. (2019). *Measuring and calculating carbon stocks - Field measurements for estimating land-based carbon stocks (SNI 7724:2019)*. Indonesian National Standards.

South Korea Greenhouse Gas Comprehensive Information Center. (2023). *2023 National Greenhouse Gas Statistics Calculation, Report, Verification Guidelines: Coastal Wetlands Excerpt (13th Revision)*.

UNFCCC/CCNUCC CDM – Executive Board. (2010). *A/R Methodological Tool 'Calculation of the number of sample plots for measurements within A/R CDM project activities' (Version 02.1.0)*.

Verra. (2023). *REDD+ Methodology Framework (VM0007, Version 1.7)*.

Verra. (2023). *Methodology for Tidal Wetland and Seagrass Restoration (VM0033, Version 2.1)*.

Verra. (n.d.). *Estimation of Carbon Stocks in the Above- and Belowground Biomass in Live Tree and Non-Tree Pools (VMD0001, Version 1.2)*.

Verra. (n.d.). *Estimation of Carbon Stocks in the Dead-wood Pool (VMD0002, Version 1.1)*.

Verra. (n.d.). *Estimation of Carbon Stocks in the Litter Pool (VMD0003, Version 1.1)*.

Verra. (n.d.). *Estimation of Carbon Stocks in the Soil Organic Carbon Pool (VMD0004, Version 1.1)*.

Verra. (n.d.). *LK-ASP: Estimation of Leakage Emissions Due to Activity Shifting for Projects Preventing Planned Deforestation (VMD0009, Version 1.3)*.

Verra. (n.d.). *LK-ASU: Estimation of Emissions from Activity Shifting for Avoiding Unplanned Deforestation and Avoiding Unplanned Wetland Degradation (VMD0010, Version 1.2)*.

Verra. (2023). *Estimation of Emissions from Market-effects (VMD0011, Version 1.2)*.

Verra. (2023). *Methods for Stratification of the Project Area (VMD0016, Version 1.3)*.

Verra. (n.d.). *LK-ARR: Estimation of Emissions from Displacement of Pre-Project Agricultural Activities (VMD0043, Version 1.0)*.

Verra. (n.d.). *LK-ECO: Estimation of Emissions from Ecological Leakage (VMD0044, Version 1.1)*.

Verra. (2024). *Additionality Assessment (VT0008, Version 1.0)*.

Verra. (2024). *Combined Baseline and Additionality Assessment (VT0009, Version 1.0)*.

Xiamen University. (2022). *Methodology for the Mangrove Forest Restoration Carbon Sink Project in Fujian Province (Version V01)*.

