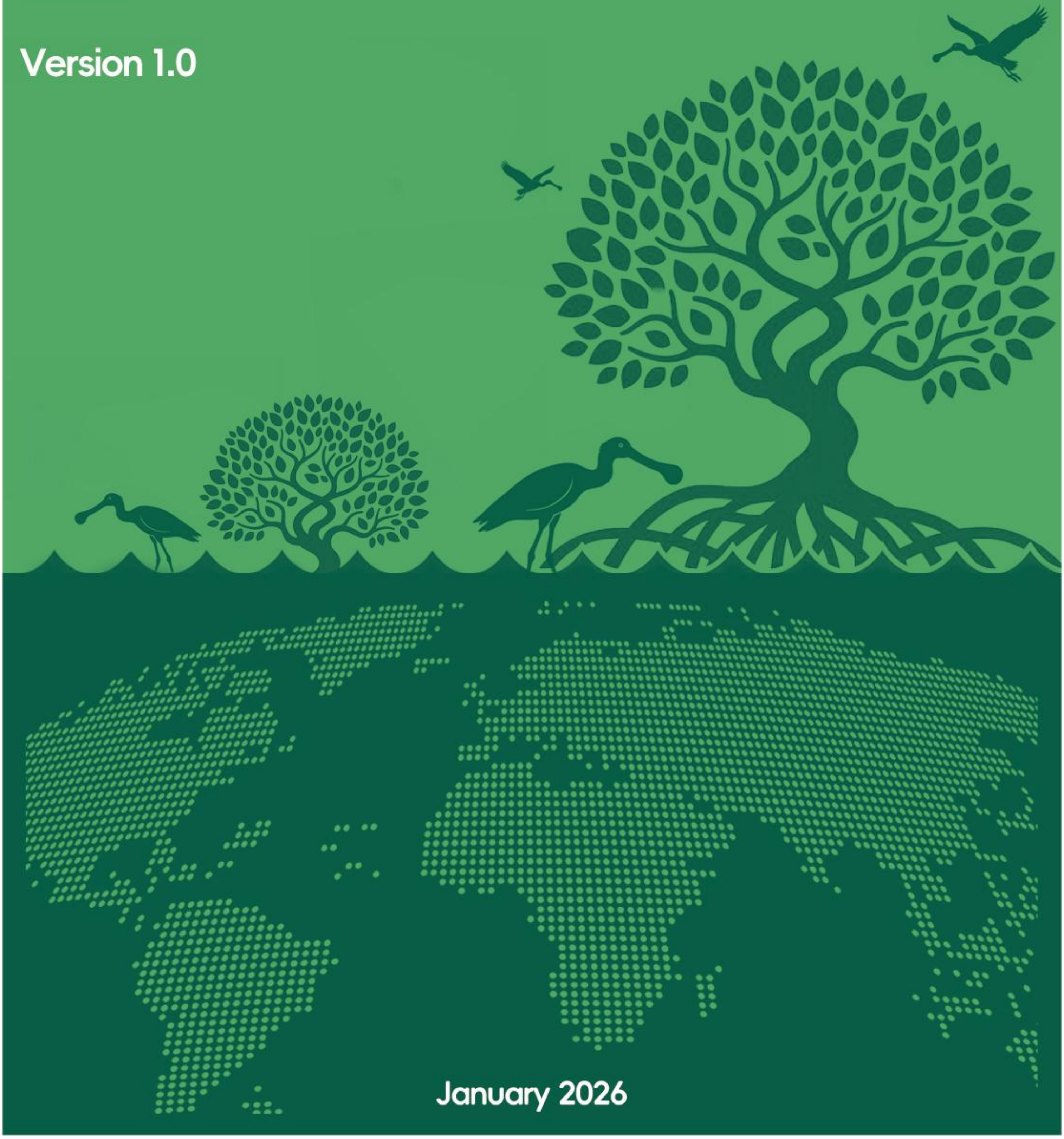
Methodology
for Mangrove Conservation

Version 1.0



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Compilation Note

Mangroves play a crucial role in coastal ecosystems and perform many vital ecological functions, such as improving water quality, protecting against storm surges, mitigating sea-level rise, capturing sediment, storing carbon, and providing habitats for coastal species. The conservation of mangrove forests has become an international consensus. Yet, as urbanization intensifies globally, the area of mangroves continues to decrease at an annual rate of 0.7%. Against the backdrop of escalating global climate challenges, leveraging carbon trading mechanisms to incentivize carbon sequestration and enhance carbon sinks in mangrove ecosystems has become an important strategic option for international organizations and their member countries in formulating climate change strategies and pathways.

Sustaining the carbon sequestration and enhancement capabilities of mangrove ecosystems is of vital importance in achieving the 'dual carbon' goals. In October 2021, the State Council of China released the *Action Plan for Carbon Emission Peak Before 2030*, which emphasized advancing the comprehensive protection and restoration of marine ecosystems and enhancing the carbon sequestration capacity of mangrove ecosystems and other similar ecosystems. The white paper on *Responding to Climate Change: China's Policies and Actions were* also released in the same month, stressing the significance of continuously enhancing ecological carbon sinks and implementing mangrove protection and restoration initiatives. Guided by national policies, various entities in China are expected to continuously carry out mangrove protection activities in the future. To scientifically quantify the carbon sequestration from mangrove conservation projects and regulate domestic workflows for designing project documentation, measuring and monitoring carbon sequestration, preparing monitoring reports, and verifying carbon credits. Ensure that mangrove conservation carbon sink projects deliver multiple benefits, including mitigating climate change, promoting sustainable development in local communities, and protecting biodiversity. Advance the use of market mechanisms to channel funds toward mangrove conservation activities, thereby achieving efficient resource allocation and further safeguarding mangrove ecosystems. Urban Planning and Natural Resources Bureau of Shenzhen Municipality officially released the nation's first *Methodology for Mangrove Conservation (Trial Version)* in May 2023. This methodology highlights the integrated climate, community, and biodiversity values of mangrove conservation. It has been applied to develop mangrove conservation carbon sink projects in areas such as Futian, Shenzhen and Zhenhai Bay, Enping City. Based on the feedback and suggestions received from project developers, relevant management agencies, and various stakeholders during its two-year application, the Urban Planning and Natural Resources Bureau of Shenzhen Municipality convened experts and institutions in related fields to revise the *Methodology for Mangrove Conservation (Trial Version)* in October 2025.

The revised methodology, aimed at developing high-quality carbon credits, has been designed by integrating multiple international standards and frameworks. Complying with the requirements of *the Core Carbon Principles* (CCP) established by the Integrity Council for the Voluntary Carbon Market (ICVCM), and aligned with the *The IPCC's Good Practice Guidance for Land Use, Land-Use Change and Forestry* (GPG-LULUCF), it adopts the latest REDD+ methodology approved by the VCS Board as a primary framework. Additionally, it draws on the practical experiences of the Climate, Community and Biodiversity Standards (CCB) and the Plan Vivo Standard regarding promoting sustainable development in local communities and biodiversity conservation. This methodology has been compiled based on China's mangrove conservation experiences and after extensive discussions among experts and stakeholders in relevant fields. The revised methodology incorporates the following key additions and refinements compared to the *Methodology for Mangrove Conservation (Trial Version)*:

1. **Baseline Scenario Identification**: The revised methodology adds optional methods and steps to identify baseline scenario, including the FLUS model-enhanced approach, the CA-Markov model-enhanced approach, the baseline model approach, and the graph neural network approach.

2. **Additionality Demonstration**: Supplementary demonstrating procedure for projects not exempt from additionality arguments are included. Considering the international market application of this methodology, it provides default values for the costs of mangrove protection and restoration in major global mangrove regions, facilitating investors in conducting additionality analysis.

3. Revisions and supplements have been made to biodiversity and community-related indicators from the perspective of enhancing operational practicality.

4. Methods for measuring the soil carbon pool and soil organic carbon stock have been added.

Methodology compiled by Development Research Center for Natural Resource and Real Estate Assessment, Shenzhen and Beijing Forestry University.

Contents

1 Introduction

This methodology is formulated to promote mangrove conservation activities aimed at protecting and enhancing the carbon sequestration and sink functions of mangrove ecosystems. It provides guidance for quantifying the multiple benefits—including climate, community, and biodiversity co-benefits—generated by domestic mangrove conservation carbon sink projects. The methodology also ensures that these integrated benefits are measurable, reportable, and verifiable, while striving to maintain its consistency, conservatism, practicability, cost-effectiveness, and scalability. This methodology is developed based on the *IPCC 2006 Guidelines for National Greenhouse Gas Inventories (2019 Refinement)*, the *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC LULUCF GPG)*, the *Climate, Community and Biodiversity Standards (CCB)* developed by the Climate, Community and Biodiversity Alliance (CCBA), the *Verified Carbon Standard (VCS)* relevant to mangrove conservation jointly established by the Climate Group (CG), the International Emissions Trading Association (IETA), and the World Economic Forum (WEF), as well as the UNFCCC Clean Development Mechanism (CDM) methodology *Afforestation and Reforestation of Degraded Mangrove Habitats* (AR-AM0014, V3.0) and its associated tools. It also incorporates practical experience from China's mangrove conservation efforts and has been formulated through extensive consultation and iterative review by experts, academics, and stakeholders in relevant fields.

This methodology references the following methodologies, guidelines, and methodological tools:

IPCC 2006 Guidelines for National Greenhouse Gas Inventories (2019 Refinement)

IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003)

CCBA Climate, Community and Biodiversity Standards (CCBA, 2013)

VM0007: VCS REDD+ Methodology Framework (REDD+MF) (v1.8)

VMD0001: Estimation of carbon stocks in the above- and belowground biomass in live tree and non-tree pool (v1.2)

VMD0006: Estimation of baseline carbon stock changes and greenhouse gas emissions from planned deforestation/forest degradation and planned wetland degradation (v1.4)

VMD0007: Estimation of baseline carbon stock changes and greenhouse gas emissions from unplanned deforestation and unplanned wetland degradation (v3.3)

VMD0042: Estimation of baseline soil carbon stock changes and greenhouse gas emissions in peatland rewetting and conservation project activities (v1.1)

VMD0046: Methods for monitoring of soil carbon stock changes and greenhouse gas emissions and removals in peatland rewetting and conservation project activities (v1.1)

VMD0004: Estimation of stocks in the soil organic carbon pool (v1.1)

VMD0016: Methods for stratification of the project area (v1.3)

VMD0002: Estimation of carbon stocks in the dead-wood pool (v1.1)

VT0001: Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities (v3.0)

AR-AM0014 Afforestation and reforestation of degraded mangrove habitats (V03.0)

AR-TOOL02 Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities (V01, EB 35)

AR-TOOL14 Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities (V04.2)

AR-TOOL12 Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities (V03.1, EB 85)

AR-TOOL08 Estimation of non-CO2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity (V04.0)

A6.4-SBM015-A11 Standard: Demonstration of additionality in mechanism methodologies (V01.0)

A6.4-SBM016-A12 Standard: Setting the baseline in mechanism methodologies (V01.0)

2 Applicability Conditions

This methodology is applicable to project activities aimed at protecting mangrove ecosystems, preventing carbon emissions and biodiversity loss caused by mangrove reduction or degradation, and revitalizing rural areas. The applicability conditions are as follows:

(a) Project activities shall comply with laws, regulations, policy measures, and relevant technical standards or procedures related to mangrove conservation issued by national and local governments;

(b) Sea areas and land within the project boundary have clear ownership;

(c) In the absence of the proposed mangrove conservation carbon sink project activities, some or all mangrove areas within the project boundary would undergo land-use conversion;

(d) The project activities shall not lead to the displacement of pre-existing activities from within the project area;

(e) The project activities shall not involve the removal of deadwood, tree roots, fruits, or similar materials；

Furthermore, other relevant applicability conditions specified in related sections of this methodology shall also be met.

3 Normative References

The following documents are indispensable for application of this methodology:

(1) GB/T 41198-2021, *Guidelines for validation and verification of forestry carbon projects*

(2) GB/T 44592-2024, *Code of practice for ecological protection and restoration of mangroves*

(3) GB/T 45140-2025, *Technical guideline for monitoring and effectiveness evaluation of mangrove ecological restoration*

(4) LY/T 1938-2011, *Technical regulations for mangrove plantation*

4 Definitions

The following terms used in this methodology are defined as follows:

Mangrove: A woody plant community growing in coastal intertidal wetlands of tropical and subtropical regions, excluding non-woody mangrove plants such as *Acrostichum aureum* and *Acrostichum speciosum* Willd.

Mangrove Ecosystem: An ecosystem primarily composed of mangrove plants, which integrates other plants, animals, microorganisms, soil, and water bodies in interdependent and mutually constraining relationships, and interacts with the surrounding environment to form a unified functional system.

Baseline Scenario: A hypothetical scenario that reasonably represents the most likely land use and management practices that would occur in the project area in the absence of the proposed project.

Project Scenario: The land use and management practices implemented within the project boundary under the proposed project activities.

Project Boundary: The geographical area within which the mangrove conservation carbon sink project activities are implemented by project participants holding land ownership or usage rights. A project may be carried out across multiple discrete land parcels, each with clearly defined geographical boundaries. Wetlands located between two or more such parcels are excluded from the project boundary.

Crediting Period: The time interval during which the project scenario generates additional greenhouse gas emission reductions compared to the baseline scenario.

Baseline Carbon Sink: The sum of carbon stock changes in all carbon pools within the project boundary under the baseline scenario, minus the increase in greenhouse gas emissions within the project boundary resulting from land-use change in the baseline scenario.

Project Carbon Sink: The carbon stock changes in selected carbon pools within the project boundary under the project scenario, minus the increase in greenhouse gas emissions within the project boundary attributable to the proposed carbon sink project activities.

Leakage: Measurable increases in greenhouse gas emissions outside the project boundary caused by the proposed project activities.

Project Emission Reduction: The net carbon sink generated by the proposed project activities, calculated as the project carbon sink minus the baseline carbon sink and leakage.

Additionally: A situation in which the project carbon sink exceeds the baseline carbon sink. This additional carbon sink would not have occurred in the absence of the proposed project activities.

Carbon Pool: Components of the mangrove ecosystem that store carbon within the carbon cycle, including the aboveground biomass, belowground biomass, litter, dead wood, and soil organic matter pools.

Aboveground Biomass: All living plant material above the soil surface, including stems, aerial roots, branches, bark, leaves, flowers, and propagules (fruits or hypocotyls).

Belowground Biomass: All living root biomass of plants located below the soil surface, typically excluding fine roots (diameter ≤ 2.0 mm) that cannot be practically distinguished from the soil.

Litter: All non-living biomass with a diameter ≤5.0 cm lying above the soil surface, in various states of decomposition. This includes litterfall, humus, and fine roots that cannot be distinguished from the belowground biomass.

Dead Wood: All non-living biomass above the soil surface excluding litter, including standing dead trees, downed dead wood, as well as dead branches, roots, and stumps with a diameter ≥5.0 cm.

Soil Organic Matter: The organic matter present within a specified depth (typically 1.0 m) of mineral and organic soils (including peat), inclusive of fine roots that cannot be distinguished from the belowground biomass.

Biodiversity: The totality of genes, species, and ecosystems in a given region, encompassing three hierarchical levels: genetic diversity, species diversity, and ecosystem diversity.

Community: A social living collective composed of people residing within a specific geographical area.

5 Baseline and Carbon Accounting Method

5.1 Project Boundary

The mangrove conservation carbon sink project area may comprise multiple discrete parcels, each with clearly defined geographical boundaries. The project boundary shall be determined using one of the following methods:

(a) Direct field surveying using satellite positioning systems such as the BeiDou Navigation Satellite System (BDS) to determine coordinate points at boundary vertices, with a single-point positioning error not exceeding ±5 meters;

(b) Direct extraction of boundary coordinates using high-resolution geospatial data (e.g., satellite imagery, aerial photography) and mangrove distribution maps with the support of a Geographic Information System (GIS).

During the project implementation phase, the project boundary may be determined using either method (a) or (b) described above, with the area measurement error not exceeding 5%.

For project validation and verification, project participants shall submit vector graphic files of the project boundary generated by GIS. During project validation, project participants must provide evidence of land ownership or usage rights for at least two-thirds of the total project area's mangrove zones. By the time of the first verification, project participants shall submit evidence of land ownership or usage rights for all project parcels.

5.2 Carbon Pools and Greenhouse Gas Emission Source

This methodology specifies the selection of carbon pools for project activities as shown in Table 5-1. Among these, the aboveground biomass, belowground biomass, and soil carbon pools are mandatory. The litter carbon pool is conservatively excluded from accounting due to its high turnover rate influenced by tidal flows, as conservation activities do not reduce its accumulation rate. Furthermore, project participants may choose to exclude the dead wood carbon pool based on considerations of data availability, cost-effectiveness, and the principle of conservatism.

Table 5-1 Selection of carbon pool

Carbon Pool	Whether Selected	Justification/Explanation
Aboveground biomass	Yes	Main carbon sequestration pool.
Belowground Biomass	Yes	Main carbon sequestration pool.
Dead Wood	Optional	Participants can choose to measure this carbon pool. As the implementation of project activities will enhance this pool, participants may also opt to exclude it in accordance with the principle of conservatism in emission reduction calculations.
Litter	No	Tidal flows result in high turnover and displacement of litter, and project activities will not reduce its accumulation rate. Excluding this carbon pool will not lead to overestimation of project emission reductions.
Soil organic carbon	Yes	Main carbon sequestration pool.

The GHG emission source selected within the project boundary are shown in Table 5-2:

Table 5-2 Selection of greenhouse gas emission source

Scenario	Emission Sources	Gas Type	Whether Selected	Justification/Explanation
Baseline scenario	Land-use change	CO_2	Optional	According to the methodology's applicability conditions, conversion of mangroves to other land uses within the project boundary will generate carbon emissions. To avoid overestimation of emission reductions, only emissions from the conversion of mangroves to other land categories are accounted for; emissions from subsequent human activities on the converted land are not. Project participants may choose to account for these emissions, or may more conservatively choose to exclude them.
	Mangrove ecosystem	CH_4	Yes	Microorganisms in the mangrove ecosystem conduct anaerobic decomposition of soil organic matter, releasing methane.
Project scenario	Natural disturbances	CO_2	No	CO_2 emissions from natural disturbances such as tsunamis and pest outbreaks are already accounted for within carbon stock changes.
	Mangrove ecosystem	CH_4	Yes	Microorganisms in the mangrove ecosystem conduct anaerobic decomposition of soil organic matter, releasing methane.

5.3 Project Period and Crediting Period

Project participants must clearly state the project activity start date, crediting period, and project period, along with the rationale for these choices.

The start date of project activity shall be the date on which the mangrove conservation activities commence. Project participants must provide transparent and verifiable evidence demonstrating that the project activities were implemented on or after January 1, 2010.

Crediting period refers to the time interval during which the project activity generates additional greenhouse gas emission reductions, biodiversity conservation benefits, and community development co-benefits for climate change adaptation, relative to the baseline scenario. The crediting period under this methodology shall not commence earlier than January 1, 2010, with a minimum duration of 20 years and a maximum not exceeding 60 years.

Project period refers to the entire duration from the commencement to the conclusion of the project activity.

5.4 Identification of the Baseline Scenario and Demonstration of Additionality

The identification of the baseline scenario for project activities shall be based on the principles of transparency and conservativeness, determining the carbon sequestration, community development, and biodiversity conditions in the absence of mangrove conservation activities. Project owners or other participants shall provide all data, rationale, assumptions, justifications, and documentation related to baseline scenario identification and additionality demonstration (such as relevant official approvals, raw datasets used for modeling and predictive simulations, etc.), which shall be subject to credibility assessment by an independent third-party entity.

5.4.1 Identification of the Baseline Scenario

The project developer should prioritize selecting areas that are similar to the project region in terms of socioeconomic and ecological environmental conditions as reference areas. The changes in land use in the reference areas should be used as the baseline scenario to assess the changes in land use within the project area, determining the rate of mangrove loss or degradation and conversion to other land types under the baseline scenario. The choice of reference areas does not need to be constrained by size. If comparative plots cannot be obtained, the following methods can be used to predict future land use scenarios in the project area:

1) Identification of key factors affecting mangroves

Natural factors: tidal range and frequency at the project site, salinity, sedimentation rate， coastal erosion/deposition dynamics, frequency/intensity of extreme weather events (typhoons, storm surges) , sea level rise scenarios;

Human factors: pressure from the expansion of aquaculture ponds, construction of ports/docks, reclamation activities, intensity of tourism development, effectiveness of protected area management policies, and the area of sea dike/shoreline protection construction;

Ecological process factors: possibility of mangrove spread, risks of pests and diseases, and the risk of interactions with other ecosystems (such as salt marshes and seagrass beds);

Use the above data as input for the predictive model.

2) Data Acquisition

Land use data: Collect data that reflects the historical land use of the reference area, such as Landsat TM/ETM/OLI remote sensing images of the reference area, as well as land use type raster datasets and vector datasets. The China Land Use/Cover Remote Sensing Monitoring Database can be selected as the data source (this database is currently the most accurate remote sensing monitoring data product of land use in China);

Other data: hydrological and meteorological data, socio-economic statistical data, and planning policy documents for the project area.

3) Division of project area

Divide the project area into core zone, ecological restoration zone and sustainable use zone to adapt to the driving conditions of the predictive model. No land use scenario conversion is allowed in the core zone; the ecological restoration zone allows suitable areas (such as abandoned fish ponds) to be restored to mangroves; the sustainable use zone permits the development of limited ecological aquaculture or ecotourism.

4) Construction of predictive model

The development process of mangroves requires consideration of unique factors such as tidal effects, salinity gradients, and biological migration corridors. Additionally, policy changes in the project location can impact the survival of mangroves. Traditional models have limited capability to characterize these complex nonlinear relationships, whereas the introduction of machine learning and neural network technologies can significantly improve prediction accuracy, capture complex nonlinear relationships, and optimize the simulation of spatial patterns.

When constructing a prediction model, land use type data for at least three phases of the project's region should be obtained. Data from the first and second phases are used to simulate the prediction results for the third phase. If the Kappa factor between the predicted results and the actual land use types for the third phase is greater than 0.8, the prediction model's results are considered reliable and can be used to forecast future land use scenarios in the project area. The model selection strategy, according to prediction accuracy and computational cost, are as follows:

a. FLUS model enhancement scheme: Use optimization algorithms such as Multilayer Perceptron (MLP), Convolutional Neural Network (CNN), Random Forest (RF), XGBoost, and LightGBM to substitute the neural network module of the FLUS model itself, improving the model's interpretability and prediction accuracy while retaining the spatial characteristics of the predicted results;

b. CA-Markov Model Enhancement scheme: Substitute the original transition probability calculation module in the Cellular Automata–Markov chain with neural network techniques. During the iterative allocation process that meets the total demand, introduce a multi-agent reinforcement learning algorithm to obtain the spatial allocation strategy with the highest likelihood under ecological constraints (connectivity corridors, core area protection, policy factors);

c. Basic model scheme: Use the FLUS model or CA-Markov model framework to predict future land use scenarios, while retaining the characterization of the mangrove ecosystem development process;

d. Graph neural network scheme: In situations where humanistic and economic data are difficult to obtain and field surveys cannot be conducted, techniques such as Graph Convolutional Networks (GCNs), Graph Attention Networks (GANs), and Graph SAGE can be used to directly predict future baseline scenarios based on past land use type data.

5.4.2 Demonstration of Additionality

Additionally for mangrove conservation carbon sink projects may be demonstrated through the following approaches:

a. Exemption from Demonstration

Mangrove wetlands constitute critical coastal ecosystems providing ecological functions including coastal protection against winds and waves, sediment accumulation and shoreline stabilization, carbon sequestration and storage, and biodiversity maintenance. While conserving mangroves effectively sustains these ecological services, such ecosystems remain vulnerable to disturbances from extreme climate events and human activities, require high construction and management costs, and generally represent financially unattractive investments. If no commercial activities have been carried out within the project boundary during the crediting period, the project’s additionality may be exempted from demonstration.

b. General Demonstration

Other mangrove conservation projects shall demonstrate additionality by following the procedures below:

Step 1: Common Practice Analysis. The common practice analysis serves to demonstrate that the project activities are not common practice. Common practice refers to protection activities or prescribed measures that are widely implemented by operating entities in the project region or similar regions (comparable in geographical location, environmental conditions, socio-economic context, and investment environment). Project participants shall submit transparent documentation proving that the technical measures of the proposed mangrove conservation project are fundamentally distinct from common practices in the project region or similar regions. Once the project activities are deemed not common practice, they shall be considered additional within the crediting period.

If the project activities are deemed common practice, project participants need to conduct either an "investment analysis" or a "barrier analysis" to demonstrate the project's additionality.

Step 2: Investment Analysis. The investment analysis serves to determine that the project activities are not economically or financially attractive without the revenue from greenhouse gas emission reductions. The investment analysis may be applied either as an independent procedure for additionality demonstration or used in combination with the barrier analysis (Step 3).

Mangrove conservation projects generate no economic benefits apart from revenue from emission reductions. Therefore, simple cost analysis shall be applied. If the unit area development and maintenance costs of the project activities exceed the regional reference costs (see Table 5-3), the project shall be deemed additional. Where investment analysis is applied, project participants shall provide reliable evidence supported by quantitative analysis.

Table 5-3 Reference Costs for Mangrove Conservation Projects in Different Region [1][2]

Region	Reference Costs(USD/ha)
Africa	7343
Asia (excluding China)	14678
Australia	13620
Latin America	14637
Pacific Islands	16723
United States	66230
China	25186

Step 3: Barrier Analysis. The barrier analysis serves to identify whether specific barriers exist that would prevent the implementation of the project activity, and whether the project

scenario helps to overcome such barriers. Barrier analysis maybe performed instead of or as an extension of investment analysis.

The barrier analysis includes, but is not limited to, the following three categories:

(1) Technical barriers, inter alia: lack of essential materials (e.g., planting materials), lack of skilled and adequately trained labor, insufficient knowledge of relevant laws, traditions, market conditions and technical measures, and lack of practical experience, and etc;

(2) Institutional barriers, inter alia: risks related to changes in government policies or regulations, institutional resistance to technical implementation, lack of incentive mechanisms or supportive policies, and insufficient organizational structures for project implementation, and etc;

(3) Ecological barriers, inter alia: degradation of the natural environment, occurrence of natural disasters or anthropogenic accidents, unfavorable meteorological conditions, potential biological invasions and population succession, and ecological pressures from agricultural and pastoral activities, and etc.

Project participants may encounter various implementation barriers, but it is sufficient to demonstrate the existence of one.

5.5 Stratification

Biomass distribution over the project area is not homogeneous, stratification should be carried out to improve the precision of biomass estimation. The project area shall be stratified into distinct carbon strata based on different stratification factors, including both ex-ante stratification during the project design phase and ex-post stratification during implementation.

Ex-ante stratification, used for estimating carbon stock changes, shall classify areas with no significant differences into the same carbon stratum. This classification shall comprehensively consider factors such as dominant vegetation type, vegetation canopy cover or land use type within the project boundary, as well as species composition and life form.

Ex-post stratification, applied for calculating carbon stock changes, shall be primarily based on the ex-ante stratification established during the project design phase, with adjustments made according to the actual growth conditions of the mangroves. If natural disturbances (e.g., pest outbreaks, storm surges, cold waves) or anthropogenic interference (e.g., logging) cause plant mortality, leading to increased heterogeneity within the original carbon strata, or changes in marine area use or land use types alter stratum boundaries, the project carbon strata shall be adjusted accordingly.

5.6 Baseline Scenario

5.6.1 The baseline net greenhouse gas removal by sinks

The baseline net GHG removal by sinks for mangrove conservation project primarily considers changes in carbon stocks within the mangrove ecosystem, including: changes in tree biomass, shrub biomass, vine biomass, dead wood carbon stocks, and soil organic carbon under the baseline scenario; along with increased GHG emissions resulting from mangrove degradation due to land-use changes (conversion from mangroves to cropland, construction land, or other land categories). It also includes increased GHG emissions from methane emissions inherent to the mangrove ecosystem itself. The calculating method of the baseline net GHG removal by sinks is detailed in Appendix 1.

5.6.2 Community conditions under the baseline scenario

The baseline scenario for the mangrove conservation projects primarily describes the social, economic, and cultural conditions of the local community under the baseline scenario, along with potential trends in these areas. Detailed content should include the social and economic status of the local community under the baseline scenario, land use and ownership patterns, and ecosystem services. For specific descriptions and survey methods, refer to Table 5-4.

Table 5-4 Description of Community Conditions

Description element	Description Content and Survey Methods
The social and economic conditions of the local community	Employing participatory rural appraisal and livelihood frameworks, among other methodologies, to investigate and assess the social and economic conditions within project boundary and surrounding communities. It should include basic resident information such as population size, age distribution, household structure, gender ratio, educational background, average annual income and sources, as well as expenditure categories. The types, distribution, and extent of use of resources currently utilized or potentially usable by local community residents.
Land use and ownership	Describe the land use within the project boundary, as well as land ownership, usage rights, and usage periods.
Ecosystem services	Describe the ecosystem service functions and values within the project boundary, as well as their impact on the lives of local and surrounding communities.

5.6.3 Biodiversity conditions under the baseline scenario

The biodiversity conditions under the baseline scenario for mangrove conservation project primarily describe the original biodiversity conditions and potential trends under the baseline scenario. Detailed content should include: survival status of wild species, high conservation values related to biodiversity, potential threats to biodiversity and description of biodiversity landscape pattern. For specific descriptions and survey methods, refer to Table 5-5.

Table 5-4 Description of Biodiversity Conditions

Description element	Description Content and Survey Methods
Survival status of wildlife species	Apply methods such as key species habitat analysis and corridor analysis to describe the survival status of wildlife species within the project area under the baseline scenario
High conservation values related to biodiversity in the project area	Using existing historical documents and scientific research findings, conduct literature reviews and field interviews to investigate whether any rare and endangered species in the project area were listed on the IUCN Red List or designated as national or local key protected species prior to the project's commencement.
Potential threats to biodiversity	Investigate factors threatening biodiversity at the project site through historical documents, field interviews, and aerial imagery collection： a Residential and Commercial Development: Investigate the status and scope of land designated for commercial and service industries, industrial and mining operations, residential use, public administration and public services, special-purpose land, and transportation infrastructure; b Energy Production and Mining: Investigate mining, quarrying, oil and gas drilling exploration, and related activities; c Biological Resource Utilization: Investigate human hunting and gathering activities for commercial, entertainment, and research purposes; d Human Disturbance: Investigate recreational activities (tourism, camping, bringing pets, etc.) and military exercises, etc. e Changes in natural ecosystems: fires and dam construction, etc. Based on actual conditions, investigations into the pathways of introduction for invasive alien species may also be conducted. Describe whether the project zone includes any of the following categories maintained by China, international organizations, or other countries/regions: invasive alien species, quarantine pests, hazardous pests, or other harmful organisms. Simultaneously investigate all potential pathways for introducing alien species into the socioeconomic activities of the project area, including the introduction, production, processing, trade, import, and export of alien species, as well as other trade, transportation, and tourism activities.
Biodiversity Landscape Patterns	Using indicators such as species richness and diversity, landscape connectivity, habitat fragmentation, and habitat types and diversity, to describe the biodiversity landscape patterns within the project area under the baseline scenario.

5.7 Project Scenario

5.7.1 The Actual net greenhouse gas removal by sinks

The actual net GHG removal by sinks equals the sum of carbon stock changes in all carbon pools within the project boundary, minus the increase in greenhouse gas emissions generated within the project boundary. The increase in greenhouse gas emissions from mangrove forests within the project area under the project scenario is primarily attributable to the additional methane emissions generated by the mangrove ecosystems. The calculating method of the actual net GHG removals by sinks is detailed in Appendix 2.

5.7.2 Leakage

Under the applicability conditions of this methodology, project activities will not lead to shift in future potential land use within the project boundary, nor will emissions from the use of transport vehicles and fuel-powered machinery during project activities be considered. Therefore, under this methodology, mangrove conservation activities do not account for potential leakage, LK_t=0, where LK_t represents the leakage emissions generated by project activities in year t.

5.7.3 Net anthropogenic greenhouse gas removals by sinks

Net anthropogenic GHG removals by sinks equal the actual net GHG removal by sinks minus the baseline net GHG removal by sinks, and minus the leakage caused by project activities. The calculating method of the net anthropogenic GHG removals by sinks is detailed in Appendix 3.

5.7.4 Community conditions under the project scenario

The community under the project scenario primarily assesses the positive and negative impacts of project activities in the social, economic, and cultural aspects of the local community, land use patterns, and ecosystem services within the project scenario. Detailed evaluation content and methodologies follow the baseline scenario community status description, as detailed in Table 5-4.

5.7.5 Biodiversity conditions under the project scenario

The biodiversity under the baseline scenario primarily assesses the positive and negative impacts of project activities within the project area on wildlife survival, conservation of high-value species for biodiversity protection, potential threats to biodiversity, and biodiversity landscape patterns under the project scenario. The evaluation content and methodology follow the baseline scenario biodiversity status description, as detailed in Table 5-5.

6 Monitoring Procedure

Project participants should develop a detailed monitoring plan when preparing project design documents, provide monitoring reports, and verify all necessary supporting documentation and data. Unless otherwise specified in the monitoring data/parameter table, comprehensive monitoring and measurement should be conducted in accordance with relevant standards. All data collected during the monitoring process should be archived in both electronic and paper formats for at least two years after the end of the accounting period.

6.1 Monitoring Carbon Benefit

6.1.1 Monitoring baseline net greenhouse gas removal by sinks

Monitoring Baseline net greenhouse gas removal by sinks is determined during the project design phase when preparing the project design document. Once a project is approved, it remains valid throughout its accounting period, thus eliminating the need for monitoring baseline net greenhouse gas removal by sinks.

6.1.2 Monitoring project boundary

(1) All boundary changes shall utilize the BDS or other satellite navigation systems to directly determine the coordinates of the corner points defining the project parcel boundaries through single-point positioning or differential techniques. High-resolution geospatial data (such as satellite imagery and aerial photographs) can also be utilized to directly read the boundary coordinates of project parcels with the assistance of a Geographic Information System (GIS). Describe the coordinate system used in the monitoring report and the accuracy of the instruments and equipment employed;

(2) Verify whether the actual boundary coordinates match those described in the project design documents;

(3) If the actual boundary lies outside the boundary described in the project design documents, the portion located beyond the boundary established in the project design documents could not be included in the monitoring scope;

(4) If the actual boundary lies within the boundary described in the project design documents, the actual boundary shall prevail;

(5) Input the measured turning point coordinates or project boundary into the GIS to calculate the area of the project site and each carbon layer;

(6) During the accounting period, project boundary may be monitored regularly. Should any changes occur, such as deforestation, the geographic coordinates and area of the deforested land

should be measured and documented during the next verification. The deforested plots will be removed from the project boundary and will no longer be monitored thereafter. They cannot be reincorporated into the project boundary. However, if these parcels have undergone verification prior to the project boundary adjustment, their previously verified carbon stock should remain unchanged and be included in the calculation of carbon stock changes.

6.1.3 Stratification update

During project implementation, the carbon stratum during the project design phase may require updating at each monitoring interval due to the presence of the following factors:

(1) Unforeseeable disturbances may occur during the crediting period, thereby increasing variability within the carbon stratum;

(2) Land use change occurs (the project site is converted to other land use types);

(3) Past monitoring has revealed variability in carbon stocks within the layer and their changes. Carbon stratum exhibiting excessive variability may be subdivided into two or more distinct carbon stratum. Carbon stratum exhibiting similar variability may be consolidated into a single stratum;

(4) Carbon stratum identified during the design phase or the previous monitoring cycle may no longer exist.

6.1.4 Sampling design

This methodology requires achieving 90% accuracy at a 90% confidence level. If the measurement accuracy falls below this value, project participants may increase the number of sample plots to ensure the results meet the accuracy requirements. The calculation method for the number of sample plots required for project monitoring is detailed in Appendix 4.

6.1.5 Plot setup

Project participants should determine and estimate carbon stocks change within relevant carbon pools using the carbon stock change method based on the continuous measurement approach for fixed plots. Within the carbon layers of each project, the spatial allocation of sample plots employs a random starting point and systematic placement.

To avoid edge effects, the edge of the plot should be at least 10 meters away from the boundary of the field.

When measuring and monitoring changes in carbon stocks within project boundary, rectangular or circular plots may be used. The plot area ranges from 100 to 600 m^2. All plots within the same mangrove forest carbon sink conservation project should have identical areas. In addition, the recommended sampling depth for assessing mangrove soil carbon stocks is 100 cm. Undisturbed sediment cores should be collected using a soil corer, and each core should be sectioned into predetermined depth intervals (e.g., 0–15 cm, 15–30 cm, 30–50 cm, 50–100 cm).

The selected plots should ensure that mangrove conservation activities within them are fully consistent with those outside the plots within the project boundary, and should strive to ensure that the plots are evenly distributed within the carbon layer.

6.1.6 Monitoring frequency

Following project initiation, monitoring of mangrove ecosystem carbon stocks shall be conducted at intervals of 3 to 8 years. Monitoring frequency may be increased beyond the original schedule in response to sudden or exceptional events, such as severe tropical storms, rapid sea-level rise, or changes in land use practices.

6.1.7 Determination of forest biomass carbon stocks

Determination of carbon stock in forest biomass is detailed in Appendix 5.

6.1.8 Determination of shrub biomass carbon stocks

The carbon stock and its variation in shrub biomass within the project boundary were estimated during the project design phase. In accordance with the principles of conservatism and cost-effectiveness, project participants may choose to discontinue monitoring of the project. However, if project activities or boundaries change, project participants shall recalculate the shrub biomass carbon stock and its variation within the project boundary using the default methodology from the project design phase, based on the adjusted project boundary and stratification. Determination of carbon stock in shrub biomass is detailed in Appendix 6.

6.1.9 Determination of vine biomass carbon stocks

Changes in vine biomass carbon stocks within the project boundary were estimated during the project design phase. In accordance with the principles of conservatism and cost-effectiveness, project participants may choose to discontinue monitoring of the project. However, if project activities or boundaries change, project participants shall recalculate the vine biomass carbon stock and its variation within the project boundary using the methodology from the project design phase, based on the adjusted project boundary and stratification. Project participants may also opt to estimate vine biomass carbon stocks through field measurements. Determination of carbon stock in vine biomass is detailed in Appendix7.

6.1.10 Determination of dead wood biomass carbon stocks

Project participants may opt to determine this by multiplying the measured forest biomass carbon stock by a default factor. Alternatively, the biomass carbon stock of dead wood can be estimated through field measurements. During field surveys, measurements and calculations should be conducted separately for standing dead tree and downed dead trees (uprooted fallen trees should be calculated as standing dead trees). Determination of carbon stock in dead wood biomass is detailed in Appendix 8.

6.1.11 Determination of soil organic carbon stock

Changes in soil organic carbon storage within the project boundary were estimated during the project design phase. In accordance with the principles of conservatism and cost-effectiveness, project participants may choose to discontinue monitoring of the project. However, if project activities or boundaries change, project participants shall recalculate the soil organic carbon storage and its variation within the project boundary using the methodology from the project design phase, based on the adjusted project boundary and stratification. Determination of soil organic carbon stock is detailed in Appendix 9.

6.1.12 Accuracy control and calibration

This methodology requires that the determination of carbon stocks achieves a precision of 90% at a 90% confidence level.

If the measurement uncertainty exceeds 10%, project participants may increase the number of sample plots to meet precision requirements. Project participants may also choose the following methods.

If $\Delta C_{PROJ,t} > 0$, then：

$$\Delta C_{TOTAL,t} = \Delta C_{PROJ,t} \cdot (1 - DR)$$

If $\Delta C_{PROJ,t} < 0$, then：

$$\Delta C_{TOTAL,t} = \Delta C_{PROJ,t} \cdot (1 + DR)$$

Where:

$\Delta C_{TOTAL,t}$ = Annual change in carbon stock estimates for selected carbon pools within the project boundary in year t; $tCO_2e{\cdot}a^{-1}$

$\Delta C_{PROJ,t}$ = Annual change in carbon stock within the selected carbon pool in year t;$tCO_2e{\cdot}a^{-1}$

DR =Adjustment factors based on monitoring result uncertainty, as shown in Table 6-1

Table 6-1 Adjustment factors

Uncertainty (%)	DR(%)
≤10%	0%
＞10% and ≤20%	6%
＞20% and ≤30%	11%
＞30%	Increase the number of sample plots

6.2 Community and Biodiversity impact monitoring

6.2.1 Community impact monitoring

Project participants should develop a monitoring plan to quantify and document changes in the local community's social and economic conditions resulting from project activities. The monitoring plan should clearly specify the content of the investigation, the investigation methods and the monitoring frequency.

Project owners may employ participatory rural appraisals or semi-structured interviews to assess the project's impact on local communities during the monitoring period. Monitoring indicators are detailed in Table 6-2.

Table 6-2 Project Scenario Community Status Monitoring Indicators

Basic indicators	Additional indicators
Project activities will yield a net benefit to the community, and improving the local social or economic conditions.	Strengthen capacity for local communities to participate in climate change response actions.
The implementation of project activities contributes to local community development and mangrove protection.	Strengthen capacity development for women and promote their equal participation in project activities.
Provide detailed documentation of local stakeholder participation in the project.	Strengthen capacity building for a broad range of groups within local communities.
Develop standardized management procedures to address conflicts and disagreements that arise during project implementation.	Project design and activities should respect and align with local customs.
Determine the potential negative impacts the project may have on communities outside the	Employment opportunities generated by project activities (including management

project area.	positions) should prioritize hiring relevant stakeholders from the local community.
A plan has been developed to minimize negative impacts on the community.	Project participants ensure full protection of employee rights in accordance with relevant laws and regulations.

An evaluation shall be conducted to assess the impacts of the project activities on community conditions during the monitoring period. Based on the number of indicators achieved, projects shall be categorized into A, B, C, and D, according to the following criteria:

A: Complete all basic indicators and achieve at least 5 additional indicators.

B: Complete all basic indicators and achieve 1-4 additional indicators.

C: Complete all basic indicators

D: Failure to meet all basic indicators

6.2.2 Biodiversity impact monitoring

Project participants should develop a monitoring plan to quantify and document changes in the social and economic conditions of local communities resulting from project activities. The monitoring plan should clearly specify the content of investigation, investigation methods, and monitoring frequency.

Project participants should select appropriate biodiversity indicators for monitoring, including species richness and diversity, landscape connectivity, forest fragmentation, habitats and their diversity. Biodiversity indicators negatively impacted by project activities should also be monitored.

The project should develop an initial plan for selecting the biodiversity indicators to be monitored and determining the monitoring frequency. Potential indicators include species richness and diversity, landscape connectivity, forest fragmentation, habitats and their diversity, etc. Other biodiversity indicators negatively impacted by project activities should also be monitored. For details on monitoring indicators in table 6-3.

Table 6-3 Project Scenario Biodiversity Status Assessment Indicators

Basic indicators	Additional indicators
Compared to the baseline scenario, the project has not impacted biodiversity.	Project activities utilized only native species, or it can be demonstrated that any introduced species used in the project offer superior biodiversity benefits compared to native species.
Compared to the baseline scenario, project activities contribute to mitigating the	Project activities have effectively reduced the harm caused by invasive alien species.

endangered status of threatened flora and fauna within the project area.	
Identified the potential adverse impacts the project may cause to biodiversity outside the project boundary.	Project activities enhance soil and water conservation within the project area.
Developed a project plan to minimize negative impacts on biodiversity outside the project boundary.	Project activities contribute to enhancing the quality of forest stands in the project area.
If unmitigable negative impacts on offsite biodiversity are demonstrated, supporting evidence shall be provided to show that the project's positive biodiversity benefits within the project area outweigh these impacts, thereby proving the project's overall positive contribution to biodiversity conservation.	Describe the project implementation helps restore fragmented habitats and enhance landscape connectivity.

An evaluation shall be conducted to assess the impacts of the project activities on biodiversity during the monitoring period. Based on the number of indicators achieved, projects shall be categorized into A, B, C, and D, according to the following criteria:

A: Complete all basic indicators and achieve at least 3 additional indicators.

B: Complete all basic indicators and achieve 1-2 additional indicators.

C: Complete all basic indicators.

D: Failure to meet all basic indicators.

6.2.3 Project evaluation

Based on the local community benefits and biodiversity benefits generated by the project, the project shall be categorized into the types specified in Table 6-4. The final classification of the project into category A, B, C, or D shall be determined by the lower of the two ratings obtained from the post-implementation assessments of local community conditions and biodiversity status.

Table 6-4 Project Category Assessment

Biodiversity / Community	A	B	C	D
A	A	B	C	D
B	B	B	C	D
C	C	C	C	D
D	D	D	D	D

6.2.4 Accounting for Sustainable Development Carbon Credits Carbon Credits

Based on the project evaluation results, the project emission reductions are adjusted using the conversion factors in table 6-5 to derive the Sustainable Carbon Credit ($\Delta CSD\ ,t$). The calculation method is as follows:

If the project is categorized as Category A, no adjustment shall be made to the project's emission reductions, then: $\Delta C_{SD,t}$=$\Delta C_{NET,t}$;

If the project is categorized as Category B, a 1% reduction adjustment shall be applied to the project's emission reductions, then: $\Delta C_{SD,t}$=$\Delta C_{NET,t} - \Delta C_{NET,t} * 0.01$;

If the project is categorized as Category C, a 1% reduction adjustment shall be applied to the project's emission reductions, then: $\Delta C_{SD,t}$=$\Delta C_{NET,t} - \Delta C_{NET,t} * 0.05$;

If the project is categorized as Category D, a 1% reduction adjustment shall be applied to the project's emission reductions, then: $\Delta C_{SD,t}$=$\Delta C_{NET,t} - \Delta C_{NET,t} * 0.1$.

Table 6-5 Conversion Factors

Project Category	Conversion Factors
A	0
B	0.01
C	0.05
D	0.1

6.3 Data and Parameters That Do Not Require Monitoring

Data and parameters that do not require monitoring in Appendix 10.

6.4 Data and Parameters That Need to Be Monitored

Data and parameters that need to be monitored in Appendix 11.

7Appendix

7.1 Appendix 1 Calculation Method for the Baseline Net Greenhouse Gas Removal by Sinks

This Appendix corresponds to Section 5.6.1 of the main text.

$\Delta C_{BSL,t} = \Delta C_{BIO\_BSL,t} - \Delta GHG_{BSL,t}$	(1)
$\Delta C_{BIO\_BSL,t} = \Delta C_{TREE\_BSL,t} + \Delta C_{SHRUB\_BSL,t} + \Delta C_{VINE\_BSL,t} + \Delta C_{DW\_BSL,t} + \Delta C_{SOC\_BSL,t}$	(2)

Where:		
$\Delta C_{BSL,t}$	=	Annual baseline net greenhouse gas removal by sinks in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta C_{BIO\_BSL,t}$	=	Annual change in baseline mangrove biomass carbon stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta C_{TREE\_BSL,t}$	=	Annual change in baseline tree biomass carbon stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta C_{SHRUB\_BSL,t}$	=	Annual change in baseline shrub biomass carbon stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta C_{VINE\_BSL,t}$	=	Annual change in baseline vine biomass carbon stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta C_{DW\_BSL,t}$	=	Annual change in baseline dead wood biomass carbon stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta C_{SOC\_BSL,t}$	=	Annual change in baseline soil organic carbon (SOC) stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta GHG_{BSL,t}$	=	Annual change in greenhouse gas (GHG) emissions within the project boundary under the baseline scenario in year *t*; $tCO_2e \cdot a^{-1}$

7.1.1 Changes in baseline mangrove tree biomass carbon stock

It is assumed that the change in tree biomass of each carbon pool under the mangrove baseline scenario within a certain period (from year t_1 to t_2) is linear, and the change is estimated using the "Carbon Stock Change Method". The calculation method is as follows:

$\Delta C_{TREE\_BSL,t} = \sum_{i=1} \Delta C_{TREE\_BSL,i,t}$	(3)
$\Delta C_{TREE\_BSL,i,t} = \frac{C_{TREE\_BSL,i,t_2} - C_{TREE\_BSL,i,t_1}}{t_2 - t_1}$	(4)

Where：		
$\Delta C_{TREE\_BSL,t}$	=	Annual change in baseline tree biomass carbon stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta C_{TREE\_BSL,i,t}$	=	Annual change in baseline tree biomass carbon stock of the carbon stratum *i* in year *t*; $tCO_2e \cdot a^{-1}$
$C_{TREE\_BSL,i,t}$	=	Annual change in baseline tree biomass carbon stock of the carbon stratum *i* in year *t*; tCO_2e
t_1, t_2	=	Year t_1 and year t_2 of the baseline scenario; $t_1 \le t \le t_2$
i	=	1,2,3……is the project carbon stratum
t	=	1,2,3……is the number of years since the start of the project; a

The calculation method for mangrove tree biomass carbon stock is to convert tree biomass to carbon content using the carbon fraction of tree biomass, and then convert carbon content (tC) to carbon dioxide equivalent (tCO_2 e) using the molecular weight ratio of CO_2 to C (44/12):

$C_{TREE\_BSL,i,t} = \frac{44}{12} * \sum_{j=1} \left(B_{TREE\_BSL,i,j,t} * CF_j\right)$			(5)
Where：			
$C_{TREE\_BSL,i,t}$	=	Annual change in baseline tree biomass carbon stock of the carbon stratum *i* in year *t*; tCO_2 e	
$B_{TREE\_BSL,i,j,t}$	=	Biomass of tree species *j* in the baseline carbon stratum *i* in year *t*; td.m.	
CF_j	=	Carbon fraction of biomass of tree species *j*; tC·(t d.m.)$^{-1}$	
i	=	1,2,3……is the project carbon stratum	
j	=	1,2,3……is the tree species *j* in the baseline carbon stratum *i*	

Project participants may select one of the following methods to estimate the biomass of tree species *j* in the baseline carbon stratum *i* in year *t*:

Method I: Biomass equation method

The project party may use the "Biomass Equation Method" to estimate the biomass of tree species *j* in the baseline stratum *i* in year *t* ($B_{TREE\_BSL,i,j,t}$), and the calculation method is as follows:

Predict the diameter at breast height (*DBH*), tree height (*H*), and wood density (*ρ*) of tree species *j* in stratum *i* for different years (*t*) within the crediting period under the baseline scenario, and calculate the tree biomass using the Biomass Equation Method:

$B_{TREE\_BSL,i,j,t} = f_{AB,j}\left(DBH_{TREE\_BSL_{i,j,t}}\ H_{TREE\_BSL_{i,j,t}}\ \rho_j\right) * \left(1 + R_j\right) * N_{TREE\_BSL_{i,j,t}} * A_{BSL_i}$			(6)
Where：			
$B_{TREE\_BSL,i,j,t}$	=	Biomass of tree species *j* in the baseline carbon stratum *i* in year *t*; td.m.	
$f_{AB,j}(DBH, H, \rho)$	=	Correlation equation between aboveground biomass of tree species *j* and diameter at breast height (*DBH*), tree height (*H*), and wood density (*ρ*); t d.m·plant^{-1}	
$DBH_{TREE\_BSL_{i,j,t}}$	=	Diameter at breast height (*DBH*) of tree species *j* in the baseline carbon stratum *i* in year *t*	
$H_{TREE\_BSL_{i,j,t}}$	=	Tree height (*H*) of tree species *j* in the baseline carbon stratum *i* in year *t*	
ρ_j	=	Wood density of tree species *j*	
R_j	=	Ratio of belowground biomass to aboveground biomass of tree species *j*; dimensionless	
$N_{TREE\_BSL_{i,j,t}}$	=	Number of plants per hectare of tree species *j* in the baseline carbon stratum *i* in year *t*; plants·hm^{-2}	
A_{BSL_i}	=	Area of the baseline stratum *i*; hm^2	
i	=	1,2,3……is the project carbon stratum	
j	=	1,2,3……is the tree species *j* in the baseline carbon stratum *i*	
t	=	1,2,3……is the number of years since the start of the project; a	

If the aboveground biomass correlation equation selected for tree species *j* using the aforementioned method does not include the measurement of pneumatophore biomass, the pneumatophore biomass may be calculated separately using the following method and added to the result obtained from Equation (6) to derive the total plant biomass of the tree species:

$B_{AR\_BSL,i,j,t} = f_{AR,j}(h) * N_{AR\_BSL_{i,j,t}} * A_{BSL_i}$		(7)
Where：		
$B_{AR\_BSL,i,j,t}$	=	Pneumatophore biomass of tree species j in the baseline carbon stratum i in year t; t d.m.
$f_{AR,j}(h)$	=	Allometric equation between pneumatophore biomass of tree species j and pneumatophore height; t d.m·plant^{-1}
h	=	Height of pneumatophores of tree species j
$N_{AR\_BSL_{i,j,t}}$	=	Average number of pneumatophores per hectare of tree species j in the baseline stratum i in year t; plant·hm^{-2}
A_{BSL_i}	=	Area of the baseline carbon stratum i; hm^2
i	=	1,2,3……is the project carbon stratum
j	=	1,2,3……is the tree species j in the baseline carbon stratum i
t	=	1,2,3……is the number of years since the start of the project; a

If there is a total biomass equation for tree species j—i.e., a correlation equation between the total individual biomass (including belowground and aboveground parts) and diameter at DBH, H, and ρ—then Equation (6) can be rewritten as:

$B_{TREE\_BSL,i,j,t} = f_{TB,j}\left(DBH_{TREE\_BSL_{i,j,t}}\ H_{TREE\_BSL_{i,j,t}}\ \rho_j\right) * N_{TREE\_BSL_{i,j,t}} * A_{BSL_i}$		(8)
Where：		
$B_{TREE\_BSL,i,j,t}$	=	Biomass of tree species j in the baseline carbon stratum i in year t; t d.m.
$f_{TB,j}(DBH, H, \rho)$	=	Correlation equation between total plant biomass of tree species j and diameter at breast height (DBH), tree height (H), and wood density (ρ); t d.m·plant^{-1}
$DBH_{TREE\_BSL_{i,j,t}}$	=	Diameter at breast height (DBH) of tree species j in the baseline carbon stratum i in year t
$H_{TREE\_BSL_{i,j,t}}$	=	Tree height (H) of tree species j in the baseline carbon stratum i in year t
ρ_j	=	Wood density of tree species j
$N_{TREE\_BSL_{i,j,t}}$	=	Average number of plants per hectare of tree species j in the baseline carbon stratum i in year t; plants·hm^{-2}
A_{BSL_i}	=	Area of the baseline stratum i; hm^2
i	=	1,2,3……is the project carbon stratum
j	=	1,2,3……is the tree species j in the baseline carbon stratum i
t	=	1,2,3……is the number of years since the start of the project; a

Method II: Biomass expansion factor method

Project participants may also use the following method to calculate tree biomass:

$B_{TREE\_BSL,i,j,t} = V_{TREE\_BSL,i,j,t} * \rho_j * BEF_j * \left(1 + R_j\right) * A_{BSL_i}$		(9)
Where：		
$B_{TREE\_BSL,i,j,t}$	=	Biomass of tree species j in the baseline carbon stratum i in year t; t d.m.
$V_{TREE\_BSL,i,j,t}$	=	Volume per unit area of tree species j in the baseline carbon stratum i in

		year t; $m^3 \cdot hm^{-2}$
ρ_j	=	Wood density of tree species j
BEF_j	=	Biomass Expansion Factor (BEF) of tree species j; dimensionless
R_j	=	Ratio of belowground biomass to aboveground biomass of tree species j; dimensionless
A_{BSL_i}	=	Area of the baseline carbon stratum i; hm^2
i	=	1,2,3……is the project carbon stratum
j	=	1,2,3……is the tree species j in the baseline carbon stratum i
t	=	1,2,3……is the number of years since the start of the project; a

Method III: Average increment method

If the mangroves within the project boundary (or part of the area) have not entered the mature and stable stage, and the project participants have data on the annual change in biomass per individual or per unit area of mangroves in this area, they may directly use this data to estimate the annual tree biomass after the project starts, until the mangroves enter the mature and stable stage. After that, the change in mangrove tree biomass is assumed to be zero.

$B_{TREE\_BSL,i,j,t} = B_{TREE\_BSL,i,j,t-1} + \overline{B}_{TREE\_BSL,i,j,t} * \left(1 + R_j\right) * N_{TREE\_BSL_{i,j,t}} * A_{BSL_i}$			(10)
Where：			
$B_{TREE\_BSL,i,j,t}$	=	Biomass of tree species j in the baseline carbon stratum i in year t; t d.m.	
$B_{TREE\_BSL,i,j,t-1}$	=	Biomass of tree species j in the baseline carbon stratum i in year $t-1$; t d.m.	
$\overline{B}_{TREE\_BSL,i,j,t}$	=	Annual change in aboveground biomass per individual of tree species j in the baseline carbon stratum i; t d.m.$\cdot a^{-1} \cdot plant^{-1}$	
R_j	=	Ratio of belowground biomass to aboveground biomass of tree species j; dimensionless	
$N_{TREE\_BSL_{i,j,t}}$	=	Number of plants per unit area of tree species j in the baseline carbon stratum i in year t; $plants \cdot hm^{-2}$	
A_{BSL_i}	=	Area of the baseline carbon stratum i; hm^2	
i	=	1,2,3……is the project carbon stratum	
j	=	1,2,3……is the tree species j in the baseline carbon stratum i	
t	=	1,2,3……is the number of years since the start of the project; a	

7.1.2 Changes in baseline mangrove shrub biomass carbon stock

It is assumed that the change in shrub biomass of each stratum under the baseline scenario within a certain period (from year t_1 to t_2) is linear, and the change is estimated using the "Carbon Stock Change Method". The calculation method is as follows:

$\Delta C_{SHRUB\_BSL,t} = \sum_{i=1} \Delta C_{SHRUB\_BSL,i,t}$			(11)
$\Delta C_{SHRUB\_BSL,i,t} = \frac{C_{SHRUB\_BSL,i,t_2} - C_{SHRUB\_BSL,i,t_1}}{t_2 - t_1}$			(12)
Where：			
$\Delta C_{SHRUB\_BSL,t}$	=	Annual change in baseline shrub biomass carbon stock within the project boundary in year t; $tCO_2e \cdot a^{-1}$	
$\Delta C_{SHRUB\_BSL,i,t}$	=	Annual change in baseline shrub biomass carbon stock of the baseline	

		carbon stratum i in year t; $tCO_2e \cdot a^{-1}$
$C_{SHRUB\_BSL,i,t}$	=	Shrub biomass carbon stock of the baseline carbon stratum i in year t; $tCO_2 e$
t_1, t_2	=	Year t_1 and year t_2 of the baseline scenario, $t_1 \leq t \leq t_2$
i	=	1,2,3……is the project carbon stratum
t	=	1,2,3……is the number of years since the start of the project; a

The calculation method for the shrub biomass carbon stock of the baseline stratum i project stratum in year t is as follows:

$$C_{SHRUB\_BSL,i,t} = \frac{44}{12} * CF_S * (1 + R_S) * B_{SHRUB\_BSL_{i,t}} * A_{BSL_i} \quad (13)$$

Where：		
$C_{SHRUB\_BSL,i,t}$	=	Shrub biomass carbon stock of the baseline carbon stratum i in year t; $tCO_2 e$
CF_S	=	Carbon fraction of shrub biomass; $tC \cdot (t\ d.m.)^{-1}$
R_S	=	Ratio of belowground biomass to aboveground biomass of shrubs; dimensionless
$B_{SHRUB\_BSL_{i,t}}$		Average shrub biomass per hectare of the baseline carbon stratum i in year t; $t\ d.m \cdot hm^{-2}$
A_{BSL_i}	=	Area of the baseline carbon stratum i; hm^2
i	=	1,2,3……is the project carbon stratum
t	=	1,2,3……is the number of years since the start of the project; a
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless

The average shrub biomass per hectare can be estimated using the default value method: when shrub coverage is < 5%, the change in baseline shrub biomass carbon stock is assumed to be zero; when shrub coverage is ≥ 5%, the estimation is conducted as follows:

$$B_{SHRUB\_BSL_{i,t}} = BDR_{SF} * B_{TREE} * CC_{SHRUB\_BSL_{i,t}} \quad (14)$$

Where：		
$B_{SHRUB\_BSL_{i,t}}$	=	Average shrub biomass per hectare of the baseline carbon stratum i in year t; $t\ d.m \cdot hm^{-2}$
BDR_{SF}	=	Ratio of the average aboveground shrub biomass per hectare (when shrub coverage is 1.0) to the average aboveground tree biomass per hectare in the project implementation area; dimensionless
B_{TREE}	=	Average aboveground tree biomass per hectare; $t\ d.m \cdot hm^{-2}$
$CC_{SHRUB\_BSL_{i,t}}$	=	Shrub coverage of the baseline carbon stratum i in year t (expressed as a decimal; e.g., if coverage is 10%, then $CC_{SHRUB\_BSL_{i,t}}$ =0.10); dimensionless
i	=	1,2,3……is the project carbon stratum
t	=	1,2,3……is the number of years since the start of the project; a

7.1.3 Changes in baseline mangrove vine biomass carbon stock

Based on the principles of cost-effectiveness and conservatism, if the proportion of vine biomass carbon stock to the total carbon stock within the project boundary is less than 5%, project participants may choose to exclude vine biomass carbon stock from measurement. It is assumed that the change in vine biomass of each stratum under the baseline scenario within a certain period (from year t_1 to t_2) is linear, and the change is estimated using the "Carbon Stock Change Method". The calculation method is as follows:

$\Delta C_{VINE\_BSL,t} = \sum_{i=1} \Delta C_{VINE\_BSL,i,t}$	(15)
$\Delta C_{VINE\_BSL,i,t} = \frac{C_{VINE\_BSL,i,t_2} - C_{VINE\_BSL,i,t_1}}{t_2 - t_1}$	(16)
$C_{VINE\_BSL,i,t} = \frac{44}{12} * \sum_{j=1} (B_{VINE\_BSL,i,j,t} * CF_{V,j})$	(17)

Where:		
$\Delta C_{VINE\_BSL,t}$	=	Annual change in baseline vine biomass carbon stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta C_{VINE\_BSL,i,t}$	=	Annual change in baseline vine biomass carbon stock of the baseline carbon stratum *i* in year *t*; $tCO_2e \cdot a^{-1}$
$C_{VINE\_BSL,i,t}$	=	Vine biomass carbon stock of the baseline carbon stratum *i* in year *t*; tCO_2 e
$B_{VINE\_BSL,i,j,t}$	=	Biomass of vine *j* in the baseline carbon stratum *i* in year *t*; t d.m.
t_1, t_2	=	Year t_1 and year t_2 of the baseline scenario; $t_1 \le t \le t_2$
$CF_{V,j}$	=	Carbon fraction of vine *j* biomass; $tC \cdot (t\ d.m.)^{-1}$
i	=	1,2,3……is the project carbon stratum
t	=	1,2,3……is the number of years since the start of the project; a
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless

The project party may estimate the biomass of vine j in the baseline stratum *i* in year *t* using the following method:

$B_{VINE\_BSL,i,j,t} = f_{VINE}(\Phi) * N_{VINE\_BSL,i,t} * A_{BSL_i}$		(18)
Where:		
$B_{VINE\_BSL,i,j,t}$	=	Biomass of vine *j* in the baseline carbon stratum *i* in year *t*; t d.m.
$f_{VINE}(\Phi)$	=	Allometric equation established based on the correlation between the diameter of vines at 1.3m above the ground and their biomass; $t\ d.m \cdot plant^{-1}$
Φ	=	Diameter of vine *j* at 1.3m above the ground; cm
$N_{VINE\_BSL,i,t}$	=	Average number of vine *j* per hectare in the baseline carbon stratum *i* in year *t*; $plants \cdot hm^{-2}$
A_{BSL_i}	=	Area of the baseline stratum *i*; hm^2
i	=	1,2,3……is the project carbon stratum
t	=	1,2,3……is the number of years since the start of the project; a

7.1.4 Changes in baseline mangrove dead wood biomass carbon stock

The change in dead wood carbon stock of each stratum under the baseline scenario is estimated using the "Carbon Stock Change Method" and the "Default Value Method":

$\Delta C_{DW\_BSL,t} = \sum_{i=1} \Delta C_{DW\_BSL,i,t}$	(19)
$\Delta C_{DW\_BSL,i,t} = \frac{C_{DW\_BSL,i,t_2} - C_{DW\_BSL,i,t_1}}{t_2 - t_1}$	(20)
$C_{DW\_BSL,i,t} = C_{TREE\_BSL,i,t} * DF_{DW}$	(21)

Where：		
$\Delta C_{DW\_BSL,t}$	=	Annual change in baseline dead wood biomass carbon stock within the project boundary in year t; $tCO_2e{\cdot}a^{-1}$
$\Delta C_{DW\_BSL,i,t}$	=	Annual change in baseline dead wood carbon stock of the baseline carbon stratum i in year t; $tCO_2e{\cdot}a^{-1}$
$C_{DW\_BSL,i,t}$	=	Dead wood carbon stock of the baseline carbon stratum i in year t; tCO_2 e
$C_{TREE\_BSL,i,t}$	=	Tree biomass carbon stock of the baseline carbon stratum i in year t; tCO_2 e
DF_{DW}	=	Conservative default factor, the ratio of dead wood carbon stock to living tree biomass carbon stock within the project boundary; %
t_1, t_2	=	Year t_1 and year t_2 of the baseline scenario; $t_1 \leq t \leq t_2$
i	=	1,2,3……is the project carbon stratum

7.1.5 Changes in baseline mangrove soil organic carbon (SOC) stock

This methodology refers to *Coastal Blue Carbon: Methodology for Assessing Carbon Stocks and Carbon Emission Factors of Mangroves, Salt Marshes, and Seagrass Beds*. Under the baseline scenario, the change in soil organic carbon stock of each stratum is estimated using the soil carbon pool increment measurement method based on surface elevation monitoring:

$\Delta C_{SOC\_BSL,t} = \frac{44}{12} * \frac{1}{100} \sum_{i=1} \left(A_{BSL_i} * CAR_{BSL,t,i} * 1a\right)$	(22)
$CAR_{BSL,t,i} = 10 * SEC_{BSL,t,i} * SBD_{BSL,t,i} * CF_{Soil\_BSL,t,i}$	(23)

Where：		
$\Delta C_{SOC\_BSL,t}$	=	Annual change in baseline soil organic carbon stock within the project boundary in year t; $tCO_2e{\cdot}a^{-1}$
A_{BSL_i}	=	Area of the baseline carbon stratum i; hm^2
$CAR_{BSL,t,i}$	=	Soil sediment carbon accumulation rate (CAR) of the baseline carbon stratum i in year t; $gC.m^{-2}{\cdot}a^{-1}$
$SEC_{BSL,t,i}$	=	Surface elevation change rate (SEC) of the baseline carbon stratum i in year t; $mm{\cdot}a^{-1}$
$SBD_{BSL,t,i}$	=	Soil bulk density (SBD) of the baseline carbon stratum i in year t; $g{\cdot}cm^{-3}$
$CF_{Soil\_BSL,t,i}$	=	Soil sediment carbon content of the baseline carbon stratum i in year t; %
i	=	1,2,3……is the project carbon stratum
t	=	1,2,3……is the number of years since the start of the project; a
1a	=	one year
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless
1/100	=	Conversion factor for converting $g{\cdot}m^{-2}$ to $t{\cdot}ha^{-1}$

Observed data of surface elevation change rate (SEC) from local or similar ecological conditions can be used to calculate using Equations (22) and (23).

7.1.6 Changes in baseline mangrove biomass carbon stock

Project participants may estimate the annual change in baseline mangrove biomass carbon stock within the project boundary in year *t* using the following methods:

Method I:

The change in mangrove biomass carbon stock under the baseline scenario ($\Delta C_{BIO\_BSL,t}$) is equal to the sum of the tree biomass carbon stock change ($\Delta C_{TREE\_BSL,t}$), shrub biomass carbon stock change ($\Delta C_{SHRUB\_BSL,t}$), vine biomass carbon stock change ($\Delta C_{VINE\_BSL,t}$), dead wood carbon stock change ($\Delta C_{DW\_BSL,t}$), and soil organic carbon stock change ($\Delta C_{SOC\_BSL,t}$), which are obtained using the methods in Sections 7.1.1-7.1.5 above.

Method II:

Project participants may also select one of the following two "Default Value Methods" to estimate the annual change in baseline mangrove biomass carbon stock within the project boundary in year t, based on the actual project situation. The calculation method is as follows:

Default value method 1:

$\Delta C_{BIO\_BSL,t} = \frac{44}{12} * DV_{BI} * A_{BSL}$			(24)
Where：			
$\Delta C_{BIO\_BSL,t}$	=	Annual change in baseline mangrove biomass carbon stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$	
DV_{BI}	=	Conservative default factor: increment of mangrove biomass carbon stock per unit area per year; $tC \cdot hm^{-2} \cdot a^{-1}$	
A_{BSL}	=	Total area within the baseline project boundary; hm^2	
t	=	1,2,3……is the number of years since the start of the project; a	
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless	

Default value method 2:

$\Delta C_{BIO\_BSL,t} = \sum_{i=1} \left(\frac{C_{BIO\_BSL,t_2} - C_{BIO\_BSL,t_1}}{t_2 - t_1} \right)$			(25)
$C_{BIO\_BSL,t} = \frac{44}{12} * DV_{Bio} * A_{BSL}$			(26)
Where：			
$\Delta C_{BIO\_BSL,t}$	=	Annual change in baseline mangrove biomass carbon stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$	
$C_{BIO\_BSL,t}$	=	Baseline mangrove biomass carbon stock within the project boundary in year *t*; $tCO_2 e$	
DV_{Bio}	=	Conservative default factor: mangrove biomass carbon stock per unit area; $tC \cdot hm^{-2}$	
A_{BSL}	=	Total area within the baseline project boundary; hm^2	
t	=	1,2,3……is the number of years since the start of the project; a	
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless	

7.1.7 Changes in greenhouse gas emissions within the project boundary under the baseline scenario

Under the baseline scenario, there are two sources of the increase in greenhouse gas emissions within the project boundary: 1) changes in greenhouse gas emissions within the project boundary caused by land use conversion, with the calculation method shown in Equation (27); 2) methane emissions from the mangrove ecosystem itself, with the calculation method shown in Equation (28):

$\Delta GHG_{BSL,t} = \Delta GHG_{CL\_BSL,t} + \Delta GHG_{ME\_BSL,t}$	(27)
$\Delta GHG_{CL\_BSL,t} = \sum_{x=1} \frac{44}{12} * A_{LUC,t,x} * \beta_{LUC,x}$	(28)

Where：		
$\Delta GHG_{BSL,t}$		Annual change in greenhouse gas emissions within the project boundary under the baseline scenario in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta GHG_{CL\_BSL,t}$	=	Annual change in greenhouse gas emissions caused by land use conversion under the baseline scenario in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta GHG_{ME\_BSL,t}$	=	Annual change in methane emissions from the mangrove ecosystem within the project boundary under the baseline scenario in year *t*; $tCO_2e \cdot a^{-1}$
$A_{LUC,t,x}$	=	Area of mangrove forest land converted to the x-th land use type under the baseline scenario in year *t*; hm^2
$\beta_{LUC,x}$	=	Carbon emission factor for converting mangrove forest land to the x-th land use type; $tC \cdot hm^{-2}$
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless
t	=	1,2,3……is the number of years since the start of the project; a

$\Delta GHG_{ME\_BSL,t} = \sum_{x=1} A_{MA,BSL,t,x} * \beta_{MA,t} * GWP_{CH_4}$	(29)

Where：		
$\Delta GHG_{ME\_BSL,t}$	=	Annual change in methane emissions from the mangrove ecosystem within the project boundary under the baseline scenario in year *t*; $tCOe \cdot a^{-1}$
$A_{MA,BSL,t,x}$	=	Area of the *x-th* land use type for mangroves under the baseline scenario in year t;hm^2
$\beta_{MA,t}$	=	Methane emission factor of the mangrove ecosystem; default value 0.012 $t \cdot hm^{-2} \cdot a^{-1}$
GWP_{CH_4}	=	Global Warming Potential (GWP) of CH_4, used to convert CH_4 to CO_2 equivalent; default value 28
t	=	1,2,3……is the number of years since the start of the project; a

7.2 Appendix 2 Calculation Method for the Actual Net Greenhouse Gas Removal by Sinks

This Appendix corresponds to Section 5.7.1 of the main text.

The project carbon sequestration is equal to the sum of changes in carbon stock of each carbon pool within the project boundary minus the increase in greenhouse gas emissions generated within the project boundary, i.e.

$\Delta C_{ACTURAL,t} = \Delta C_{p,t} - \Delta GHG_{ME\_PROJ,t}$			(30)
Where：			
$\Delta C_{ACTURAL,t}$	=	Annual actual net greenhouse gas removal by sinks in year *t*; $tCO_2e\cdot a^{-1}$	
$\Delta C_{p,t}$	=	Annual change in carbon stock of selected carbon pools within the project boundary in year *t*; $tCO_2e\cdot a^{-1}$	
$\Delta GHG_{ME\_PROJ,t}$	=	Annual change in methane emissions from the mangrove ecosystem within the project boundary under the project scenario in year *t*; $tCO_2e\cdot a^{-1}$	

The calculation method for the annual change in carbon stock of selected carbon pools within the project boundary in year *t* is as follow:

$\Delta C_{P,t} = \Delta C_{BIO\_PROJ,t}$			(31)
$\Delta C_{BIO\_PROJ,t} = \Delta C_{TREE\_PROJ,t} + \Delta C_{SHRUB\_PROJ,t} + \Delta C_{VINE\_PROJ,t} + \Delta C_{DW\_PROJ,t} + \Delta C_{SOC\_PROJ,t}$			(32)
Where：			
$\Delta C_{P,t}$	=	Annual change in carbon stock of selected carbon pools within the project boundary in year *t*; $tCO_2e\cdot a^{-1}$	
$\Delta C_{BIO\_PROJ,t}$	=	Annual change in project mangrove biomass carbon stock within the project boundary in year *t*; $tCO_2e\cdot a^{-1}$	
$\Delta C_{TREE\_PROJ,t}$	=	Annual change in project tree biomass carbon stock within the project boundary in year *t*; $tCO_2e\cdot a^{-1}$	
$\Delta C_{SHRUB\_PROJ,t}$	=	Annual change in project shrub biomass carbon stock within the project boundary in year *t*; $tCO_2e\cdot a^{-1}$	
$\Delta C_{VINE\_PROJ,t}$	=	Annual change in project vine biomass carbon stock within the project boundary in year *t*; $tCO_2e\cdot a^{-1}$	
$\Delta C_{DW\_PROJ,t}$	=	Annual change in project dead wood biomass carbon stock within the project boundary in year *t*; $tCO_2e\cdot a^{-1}$	
$\Delta C_{SOC\_PROJ,t}$	=	Annual change in project soil organic carbon stock within the project boundary in year *t*; $tCO_2e\cdot a^{-1}$	

7.2.1 Changes in project mangrove tree biomass carbon stock within the project boundary

The calculation method for the change in project mangrove tree biomass carbon stock within the project boundary is as follows:

$\Delta C_{TREE\_PROJ,t} = \sum_{i=1} \Delta C_{TREE\_PROJ,i,t}$	(33)
$\Delta C_{TREE\_PROJ,i,t} = \frac{C_{TREE\_PROJ,i,t_2} - C_{TREE\_PROJ,i,t_1}}{t_2 - t_1}$	(34)

$C_{TREE\_PROJ,i,t} = \frac{44}{12} * \sum_{j=1} \left(B_{TREE\_PROJ\,,i,j,\,t} * CF_j\right)$	(35)

Where：		
$\Delta C_{TREE\_PROJ,t}$	=	Annual change in project tree biomass carbon stock within the project boundary in year t; $tCO_2e{\cdot}a^{-1}$
$\Delta C_{TREE\_PROJ,i,t}$	=	Annual change in tree biomass carbon stock of the project carbon stratum i in year t; $tCO_2e{\cdot}a^{-1}$
$C_{TREE\_PROJ,i,t}$	=	Tree biomass carbon stock of the project carbon stratum i in year t; tCO_2 e
$B_{TREE\_PROJ,i,j,\,t}$	=	Biomass of tree species j in the project carbon stratum i in year t; t d.m.
CF_j	=	Carbon fraction of biomass of tree species j; tC·(t d.m.)$^{-1}$
t_1, t_2	=	Year t_1 and year t_2 of the project scenario; $t_1 \le t \le t_2$
i	=	1,2,3……is the project carbon stratum
j	=	1,2,3……is the tree species j in the baseline carbon stratum i
t	=	1,2,3……is the number of years since the start of the project; a
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless

The estimation of tree biomass within the project boundary ($B_{TREE\_PROJ,i,j,\,t}$) can be conducted using the methods in Section 7.1.1 (Appendix 1), but it must be consistent with the method selected for the baseline scenario.

7.2.2 Changes in project mangrove shrub biomass carbon stock within the project boundary

The calculation method for the change in shrub biomass carbon stock within the project boundary is consistent with that of the baseline scenario, and the method is as follows:

$\Delta C_{SHRUB\_PROJ,t} = \sum_{i=1} \Delta C_{SHRUB\_PROJ,i,t}$	(36)
$\Delta C_{SHRUB\_PROJ,i,t} = \frac{C_{SHRUB\_PROJ,i,t_2} - C_{SHRUB\_PROJ,i,t_1}}{t_2 - t_1}$	(37)
$C_{SHRUB\_PROJ,i,t} = \frac{44}{12} * CF_S * (1 + R_S) * B_{SHRUB\_PROJ_{i,t}} * A_{PROJ_i}$	(38)

Where：		
$\Delta C_{SHRUB\_PROJ,t}$	=	Annual change in project shrub biomass carbon stock within the project boundary in year t; $tCO_2e{\cdot}a^{-1}$
$\Delta C_{SHRUB\_PROJ,i,t}$	=	Annual change in shrub biomass carbon stock of the project carbon stratum i in year t; $tCO_2e{\cdot}a^{-1}$
$C_{SHRUB\_PROJ,i,t}$	=	Shrub biomass carbon stock of the project carbon stratum i in year t; tCO_2 e
CF_S	=	Carbon fraction of shrub biomass; tC·(t d.m.)$^{-1}$
R_S	=	Ratio of belowground biomass to aboveground biomass of shrubs; dimensionless
$B_{SHRUB\_PROJ,i,\,t}$	=	Average shrub biomass per hectare of the project carbon stratum i in year t; t d.m.·hm^{-2}
A_{PROJ_i}	=	Area of the project carbon stratum i; hm^2
t_1, t_2	=	Year t_1 and year t_2 of the project scenario; $t_1 \le t \le t_2$
i	=	1,2,3……is the project carbon stratum
j	=	1,2,3……is the tree species j in the baseline carbon stratum i
t	=	1,2,3……is the number of years since the start of the project; a
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless

The estimation of shrub biomass within the project boundary ($B_{SHRUB\_PROJ,i,\,t}$) is conducted using the method in Section 7.1.1 (Appendix 1).

7.2.3 Changes in project mangrove vine biomass carbon stock within the project boundary

The calculation method for the change in mangrove vine carbon stock under the project scenario is consistent with that of the baseline scenario, and the method is as follows:

$\Delta C_{VINE\_PROJ,t} = \sum_{i=1} \Delta C_{VINE\_PROJ,i,t}$	(39)
$\Delta C_{VINE\_PROJ,i,t} = \frac{C_{VINE\_PROJ,i,t_2} - C_{VINE\_PROJ,i,t_1}}{t_2 - t_1}$	(40)
$C_{VINE\_PROJ,i,t} = \frac{44}{12} * \sum_{j=1} \left(B_{VINE\_PROJ,i,j,t} * CF_{V,j}\right)$	(41)

Where：		
$\Delta C_{VINE\_PROJ,t}$	=	Annual change in project vine biomass carbon stock within the project boundary in year *t*; $tCO_2e{\cdot}a^{-1}$
$\Delta C_{VINE\_PROJ,i,t}$	=	Annual change in vine biomass carbon stock of the project carbon stratum *i* in year *t*; $tCO_2e{\cdot}a^{-1}$
$C_{VINE\_PROJ,i,t}$	=	Vine biomass carbon stock of the project carbon stratum *i* in year *t*; tCO_2 e
$B_{VINE\_PROJ,i,j,t}$	=	Biomass of vine *j* in the project carbon stratum *i* in year *t*; t d.m.
$CF_{V,j}$	=	Carbon fraction of vine *j* biomass; $tC{\cdot}(t\ d.m.)^{-1}$
t_1, t_2	=	Year t_1 and year t_2 of the project scenario, $t_1 \le t \le t_2$
i	=	1,2,3……is the project carbon stratum
t	=	1,2,3……is the number of years since the start of the project; a
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless

The calculation of vine carbon stock under the project scenario ($C_{VINE\_PROJ,i,t}$) is also consistent with that of the baseline scenario, using the method in Section 7.1.3 (Appendix 1).

7.2.4 Changes in project dead wood carbon stock within the project boundary

The calculation method for the change in project dead wood carbon stock of each stratum within the project boundary is consistent with that of the baseline scenario, and is estimated using the method in Section 7.1.4 (Appendix 1):

$\Delta C_{DW\_PROJ,t} = \sum_{i=1} \Delta C_{DW\_PROJ,i,,t}$	(42)
$\Delta C_{DW\_PROJ,i,t} = \frac{C_{DW\_PROJ,i,t_2} - C_{DW\_PROJ,i,t_1}}{t_2 - t_1}$	(43)
$C_{DW\_PROJ,i,t} = C_{TREE\_PROJ,i,t} * DF_{DW}$	(44)

Where：		
$\Delta C_{DW\_PROJ,t}$	=	Annual change in project dead wood biomass carbon stock within the project boundary in year *t*; t $tCO_2e{\cdot}a^{-1}$
$\Delta C_{DW\_PROJ,i,t}$	=	Annual change in dead wood biomass carbon stock of the project carbon stratum *i* in year *t*; $tCO_2e{\cdot}a^{-1}$
$C_{DW\_PROJ,i,t}$	=	Dead wood biomass carbon stock of the project carbon stratum *i* in year *t*; tCO_2 e

$C_{TREE\_PROJ,i,t}$	=	Tree biomass carbon stock of the project carbon stratum *i* in year *t*; tCO_2 e
DF_{DW}	=	Conservative default factor: ratio of dead wood carbon stock to living tree biomass carbon stock within the project boundary; %
t_1, t_2	=	Year t_1 and year t_2 of the project scenario; $t_1 \leq t \leq t_2$
i	=	1,2,3……is the project carbon stratum
t	=	1,2,3……is the number of years since the start of the project; a

7.2.5 Changes in project soil organic carbon stock within the project boundary

The calculation method for the change in mangrove soil organic carbon (SOC) stock under the project scenario is consistent with that of the baseline scenario, and is estimated using the method in Section 7.1.5 (Appendix 1):

$\Delta C_{SOC\_PROJ,t} = \frac{44}{12} * \frac{1}{100} \sum_{i=1} \left(A_{PROJ_i} * CAR_{PROJ,t,i} * 1a \right)$		(45)
$CAR_{PROJ,t,i} = 10 * SEC_{PROJ,t,i} * SBD_{PROJ,t,i} * CF_{Soil\_PROJ,t,i}$		(46)
Where：		
$\Delta C_{SOC\_PROJ,t}$	=	Annual change in project soil organic carbon (SOC) stock within the project boundary in year *t*; tCO_2-e·a^{-1}
A_{PROJ_i}	=	Area of the project stratum *i*; hm^2
$CAR_{PROJ,t,i}$	=	Soil sediment carbon accumulation rate (CAR) of the project carbon stratum *i* in year *t*; gC.m^{-2}·a^{-1}
$SEC_{PROJ,t,i}$	=	Surface elevation change rate (SEC) of the project carbon stratum *i* in year *t*; mm·a^{-1}
$SBD_{PROJ,t,i}$	=	Soil bulk density (SBD) of the project carbon stratum *i* in year *t*; g·cm^{-3}
$CF_{Soil\_PROJ,t,i}$	=	Soil sediment carbon content of the project carbon stratum *i* in year *t*; %
i	=	1,2,3……is the project carbon stratum
t	=	1,2,3……is the number of years since the start of the project; a
1a	=	One year
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless
1/100	=	Conversion factor for converting g·m^{-2} to t·ha^{-1}

7.2.6 Changes in project mangrove biomass carbon stock within the project boundary

The calculation method for the change in mangrove biomass carbon stock within the project boundary is consistent with that of the baseline scenario, and is estimated using the method in Section 7.1.6 (Appendix 1).

7.2.7 Changes in greenhouse gas emissions within the project boundary under the project scenario

Under the project scenario, changes in greenhouse gas emissions within the project boundary comes from methane emissions from the mangrove ecosystem itself. Its calculation method is consistent with that of the baseline scenario, using Equation (27) in Section 7.1.7 (Appendix 1).

7.3 Appendix 3 Calculation Method for the Net Anthropogenic Greenhouse Gas Removals by Sinks

This Appendix corresponds to Section 5.6.3 of the main text.

$\Delta C_{NET,t} = \Delta C_{ACTURAL,t} - \Delta C_{BSL,t} - LK_t$		(47)
Where：		
$\Delta C_{NET,t}$	=	Annual net anthropogenic greenhouse gas removals by sinks in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta C_{ACTURAL,t}$	=	Annual actual net greenhouse gas removal by sinks in year *t*; $tCO_2e \cdot a^{-1}$
$\Delta C_{BSL,t}$	=	Annual baseline net greenhouse gas removal by sinks in year *t*; $tCO_2e \cdot a^{-1}$
LK_t	=	Leakage caused by project activities in year *t*; $tCO_2e \cdot a^{-1}$
t	=	1,2,3……is the number of years since the start of the project; a

7.4 Appendix 4 Sampling Design Method

This Appendix corresponds to Section 6.1.4 of the main text.

This methodology requires a precision of 90% at a 90% confidence level. If the measured precision is lower than this value, project participants may increase the number of sample plots to ensure the measurement results meet the precision requirement. The number of sample plots required for project monitoring can be calculated using the following methods:

(1) Calculate using Equation (48). If $n \geq 30$, the final number of sample plots is n; if $n < 30$, the t with degrees of freedom (n-1) must be used for a second iterative calculation using Equation (48), and the resulting n is the final number of sample plots;

$n = \frac{N * t_{VAL}{}^2 * \left(\sum_i w_i * s_i\right)^2}{N * E^2 + t_{VAL}{}^2 * \sum_i w_i * s_i^2}$		(48)
Where:		
n	=	Number of monitoring sample plots required for estimating biomass carbon stock within the project boundary; dimensionless
N	=	Sampling population of monitoring sample plots within the project boundary, where $N = \frac{A}{A_P}$ (A is total project area in hm²; A_P is sample plot area); dimensionless
t_{VAL}	=	Confidence indicator: t obtained from the two-tailed t-distribution table with infinite (∞) degrees of freedom at a specific confidence level; dimensionless
w_i	=	Area weight of the carbon stratum i project stratum within the project boundary, where $w_i = A_i / A$ (A is total project area in hm²; A_i is area of the stratum i project stratum in hm²); dimensionless
s_i	=	Standard deviation of the estimated biomass carbon stock of the carbon stratum i project stratum within the project boundary; tC/hm^2
E	=	Allowable error range of the estimated project biomass carbon stock (i.e., half of the confidence interval), represented by s_i within each stratum; tC/hm^2
i	=	1,2,3……is the project carbon stratum

(2) When the sampling area is large (sampling area > 5% of the project area), after calculating the number of sample plots (n) using Equation (48), adjust n using Equation (49) to determine the final number of sample plots (n_a):

$n_a = n * \frac{1}{1+n/N}$		(49)
Where:		
n_a	=	Adjusted number of monitoring sample plots required for estimating biomass carbon stock within the project boundary; dimensionless
n	=	Number of monitoring sample plots required for estimating biomass carbon stock within the project boundary; dimensionless
N	=	Sampling population of monitoring sample plots within the project boundary; dimensionless

(3) When the sampling area is small (sampling area < 5% of the project area), the simplified Equation (50) can be used for calculation:

$n = \left(\frac{t_{VAL}}{E}\right)^2 * \left(\sum_i w_i * s_i\right)^2$		(50)
Where:		
n	=	Number of monitoring sample plots required for estimating biomass carbon stock within the project boundary; dimensionless
t_{VAL}	=	Confidence indicator: t-value obtained from the two-tailed t-distribution table with infinite (∞) degrees of freedom at a specific confidence level; dimensionless
w_i	=	Area weight of the project carbon stratum i within the project boundary, where $w_i = A_i / A$ (A is total project area in hm²; A_i is area of the project carbon stratum i in hm²); dimensionless
s_i	=	Standard deviation of the estimated biomass carbon stock of the project carbon stratum i within the project boundary; tC/hm²
E	=	Allowable error range of the estimated project biomass carbon stock (i.e., half of the confidence interval), represented by s_i within each stratum; tC/hm²
i	=	1,2,3……is the project carbon stratum

(4) The number of monitoring sample plots allocated to each mangrove type is calculated using the optimal allocation method and Equation (51):

$n = n_i = n * \frac{w_i * s_i}{\sum_i w_i * s_i}$		(51)
Where:		
n_i	=	Number of monitoring sample plots required for estimating biomass carbon stock of the project carbon stratum i within the project boundary; dimensionless
n	=	Number of monitoring sample plots required for estimating biomass carbon stock within the project boundary; dimensionless
w_i	=	Area weight of the project carbon stratum i within the project boundary, where $w_i = A_i / A$ (A is total project area in hm²; A_i is area of the project carbon stratum i in hm²); dimensionless
s_i	=	Standard deviation of the estimated biomass carbon stock of the project carbon stratum i within the project boundary; tC/hm²
i	=	1,2,3……is the project carbon stratum

7.5 Appendix 5 Method for Determining Tree Biomass Carbon Stock

This Appendix corresponds to Section 6.1.7 of the main text.

Step 1: Conduct per-tree measurement in the sample plot. Measure the diameter at breast height (*DBH*), tree height (*H*), and/or wood density (ρ) of all living trees in the plot; the minimum measurable *DBH* is 3 cm. Determine whether to measure the height of pneumatophores (h) in the plot based on the biomass equation used for actual calculation. If the selected biomass equation already includes the measurement of pneumatophore biomass, measuring h is unnecessary; otherwise, measure h of all pneumatophores in the plot and establish an allometric equation between pneumatophore height and biomass using the measured data;

Step 2: Calculate the tree biomass of each tree species in the plot using the biomass equation method. Sum the tree biomass of all tree species in the plot to obtain the plot-level biomass. Based on the plot tree biomass, calculate the plot-level tree biomass carbon stock and the average tree biomass carbon stock per unit area of each stratum;

Step 3: Calculate the sample mean (estimated value of average tree biomass carbon stock per unit area) and its variance of stratum *i* using Equations (52) and (53):

$c_{TREE,i,t} = \frac{\sum_{p=1}^{n_i} c_{TREE,i,p,t}}{n_i}$			(52)
Where：			
$c_{TREE,i,t}$	=	Estimated value of average tree biomass carbon stock per unit area of the project carbon stratum *i* in year *t*; $tCO_2e{\cdot}hm^{-2}$	
$c_{TREE,i,p,t}$	=	Tree biomass carbon stock per unit area of sample plot p in the project carbon stratum *i* in year *t*; $tCO_2e{\cdot}hm^{-2}$	
n_i	=	Number of sample plots in the project carbon stratum *i*	
i	=	1,2,3……is the project carbon stratum	
p	=	1,2,3……is sample plot in the project carbon stratum *i*	
t	=	1,2,3……is the number of years since the start of the project; a	

$S^2_{c_{TREE,i,t}} = \frac{\sum_{p=1}^{n_i} (c_{TREE,i,p,t} - c_{TREE,i,t})^2}{n_i * (n_i - 1)}$			(53)
Where：			
$S^2_{c_{TREE,i,t}}$	=	Variance of the estimated average tree biomass carbon stock per unit area of the project carbon stratum *i* in year *t*; $(tCO_2e{\cdot}hm^{-2})^2$	
$c_{TREE,i,p,t}$	=	Tree biomass carbon stock per unit area of sample plot p in the project carbon stratum *i* in year *t*; $tCO_2e{\cdot}hm^{-2}$	
$c_{TREE,i,t}$	=	Estimated average tree biomass carbon stock per unit area of the project carbon stratum *i* in year *t*; $tCO_2e{\cdot}hm^{-2}$	

i	=	1,2,3……is the project carbon stratum
p	=	1,2,3……is sample plot in the project carbon stratum *i*
t	=	1,2,3……is the number of years since the start of the project; a

Step 4: Calculate the estimated project population mean (estimated average tree biomass carbon stock per unit area) and its variance using Equations (54) and (55):

$c_{TREE,t} = \sum_{i=1}^{M} (w_i * c_{TREE,i,t})$			(54)
Where：			
$c_{TREE,t}$	=	Estimated average tree biomass carbon stock per unit area within the project boundary in year *t*; $tCO_2e \cdot hm^{-2}$	
w_i	=	Ratio of the area of the project carbon stratum *i* to the total project area, where $wi = Ai/A$; dimensionless	
$c_{TREE,i,t}$	=	Estimated average tree biomass carbon stock per unit area of the project carbon stratum *i* in year *t*; $tCO_2e \cdot hm^{-2}$	

$S^2_{c_{TREE,t}} = \sum_{i=1}^{M} (w_i{}^2 * \frac{S^2_{c_{TREE,i,t}}}{n_i})$			(55)
Where：			
$S^2_{c_{TREE,t}}$	=	Variance of the estimated project population mean (average tree biomass carbon stock per unit area) in year *t*; $(tCO_2e \cdot hm^{-2})^2$	
w_i	=	Ratio of the area of the project carbon stratum *i* to the total project area, where $w_i = Ai/A$; dimensionless	
$S^2_{c_{TREE,i,t}}$	=	Variance of the estimated average tree biomass carbon stock per unit area of the project carbon stratum *i* in year *t*; $(tCO_2e \cdot hm^{-2})^2$	
n_i	=	Number of sample plots in the project carbon stratum *i*	
M	=	Total number of strata for estimating tree biomass carbon stock within the project boundary	
i	=	1,2,3……is the project carbon stratum	
t	=	1,2,3……is the number of years since the start of the project; a	

Step 5: Calculate the uncertainty of the estimated average tree biomass carbon stock per unit area within the project boundary using Equation (56):

$u_{c_{TREE,t}} = \frac{t_{VAL} * S_{c_{TREE,t}}}{c_{TREE,t}}$			(56)
Where：			
$u_{c_{TREE,t}}$	=	Uncertainty (relative error limit) of the estimated average tree biomass carbon stock per unit area within the project boundary in year *t*; %. The relative error must be ≤ 10% (i.e., sampling precision ≥ 90%).	
t_{VAL}	=	Confidence indicator: degrees of freedom = *n* - *M* (n = total number of sample plots within the project boundary; M = total number of strata for tree biomass estimation). It is obtained from the two-tailed t-distribution table at a 90% confidence level. Example: At a 90% confidence level with 45 degrees of freedom, the two-tailed t-value can be calculated in Excel using the formula "= TINV (0.10,45)", resulting in a t-value of 1.6794.	

$S_{c_{TREE,t}}$	=	Square root of the variance (i.e., standard error) of the estimated average tree biomass carbon stock per unit area within the project boundary in year *t*; $tCO_2e \cdot hm^{-2}$
$c_{TREE,t}$	=	Estimated average tree biomass carbon stock per unit area within the project boundary in year *t*; $tCO_2e \cdot hm^{-2}$

Step 6: Calculate the total tree biomass carbon stock within the project boundary in year *t* using Equation (57):

$C_{TREE,t} = A * c_{TREE,t}$		(57)
Where：		
$C_{TREE,t}$	=	Estimated tree biomass carbon stock within the project boundary in year *t*; tCO_2e
A	=	Total area of all strata within the project boundary; hm^2
$c_{TREE,t}$	=	Estimated average tree biomass carbon stock per unit area within the project boundary in year *t;* $tCO_2e \cdot hm^{-2}$
t		1,2,3……is the number of years since the start of the project; a

Step 7: Calculate the annual change in tree biomass carbon stock within the project boundary using Equation (58). It is assumed that the change in tree biomass is linear over a certain period:

$dC_{TREE(t_1,t_2)} = \frac{C_{TREE,t_2} - C_{TREE,t_1}}{T}$		(58)
Where：		
$dC_{TREE(t_1,t_2)}$	=	Annual change in tree biomass carbon stock within the project boundary between year t_1 and t_2; $tCO_2e \cdot a^{-1}$
$C_{TREE,t}$	=	Estimated tree biomass carbon stock within the project boundary in year *t*; tCO_2e
T	=	Time interval between two consecutive measurements ($T = t_2 - t_1$); a
t_1, t_2	=	Year t_1 and t_2 since the start of project activities; $t_1 \leq t \leq t_2$

During the first verification, assign the tree biomass carbon stock at the start of project activities to the variable $c_{TREE,i,t}$ in Equation (52); i.e., $c_{TREE,i,t_1} = c_{TREE\_BSL}$ during the first verification, where $t_1 = 0$ and t_2 = the year of the first verification.

Step 8: Calculate the change in tree biomass carbon stock within the project boundary in year *t* ($t_1 \leq t \leq t_2$) during the verification period using Equation (59):

$\Delta C_{TREE,t} = dC_{TREE(t_1,t_2)} * 1$		(59)
Where：		
$\Delta C_{TREE,t}$	=	Annual change in tree biomass carbon stock within the project boundary in year *t*; $tCO_2e \cdot a^{-1}$
$dC_{TREE(t_1,t_2)}$	=	Annual change in tree biomass carbon stock within the project boundary between year t_1 and t_2; $tCO_2e \cdot a^{-1}$
1	=	One year; a

7.6 Appendix 6 Methods for Determining Shrub Biomass Carbon Stocks

This Appendix corresponds to Section 6.1.8 of the main text.

Shrub biomass is generally correlated with diameter at ground level (DGL), number of branches, shrub height, and crown width. Therefore, biomass equations can be employed to monitor carbon stocks in the shrub biomass carbon pool.

Step 1: Establish subplot k (area ≥ 2 m², 10 m² recommended) within plot p of stratum i. Measure the diameter at ground level, shrub height, crown width, and branch count of shrubs within the subplot. Apply univariate or multivariate biomass equations and use Equation (60) to calculate the shrub biomass per unit area in plot p:

$c_{SHRUB,i,p,t} = \frac{\sum_{k=1}\sum_{j=1}[f_{SHRUB,j}(x_1,x_2,x_3\ldots) * N_{i,p,k,j,t} * CF_{S,j} * (1+R_{S,j})]}{\sum_{k=1} A_{SHRUB,i,p,k,t}} * \frac{1}{100} * \frac{44}{12}$	(60)

Where:		
$c_{SHRUB,i,p,t}$	=	Average shrub biomass carbon stock per unit area in plot p of the project carbon stratum i within the project boundary in year t; $tCO_2e \cdot hm^{-2}$
$f_{SHRUB,j}(x_1,x_2,x_3\ldots)$	=	The aboveground biomass per branch equation for shrub type j as a function of shrub measurement parameters $(x_1,x_2,x_3\ldots)$, such as diameter at ground level, shrub height, crown width, crown diameter, etc.; g d.m.·branch^{-1}
$N_{i,p,k,j,t}$	=	Number of branches of shrub type j in subplot k plot p, the project carbon stratum i; branch
$CF_{S,j}$	=	Carbon fraction of shrub type j, tC·(t d.m.)$^{-1}$
$R_{S,j}$	=	Ratio of belowground to aboveground biomass for shrub type j; dimensionless
$A_{SHRUB,i,p,k,t}$	=	Area of subplot k within plot p of the project carbon stratum i in year t; m²
i	=	1,2,3…… is the project carbon stratum
p	=	1,2,3…… is sample plot in the project carbon stratum i
k	=	1,2,3……subplot within plot p
j	=	1,2,3……shrub type j
t	=	1,2,3…… is the number of years since the start of the project; a
1/100	=	Conversion factor for converting g·m^{-2} to t·hm^{-2}
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless

Step 2: Calculate the estimated value of the average shrub biomass carbon stock per unit area and its variance for carbon stratum i. With reference to Equations (52) and (53), substitute $c_{SHRUB,i,t}$ for $c_{TREE,i,t}$, $c_{SHRUB,i,p,t}$ for $c_{TREE,i,p,t}$, and $S_{C_{SHRUB,i,t}}$ for $S_{C_{TREE,i,t}}$.

Step 3: Calculate the estimated overall mean value (i.e., the estimated average shrub biomass carbon stock per unit area) across the entire project area and its variance. With reference to Equations (54) and (55), substitute $c_{SHRUB,t}$ for $c_{TREE,t}$, $c_{SHRUB,i,t}$ for $c_{TREE,i,t}$, $S_{C_{SHRUB,t}}$ for $S_{C_{TREE,t}}$, and $S_{C_{SHRUB,i,t}}$ for $S_{C_{TREE,i,t}}$.

Step 4: Calculate the uncertainty of the estimated average shrub biomass carbon stock per unit area within the project boundary. With reference to Equation (56), substitute $u_{c_{SHRUB,t}}$ for $u_{c_{TREE,t}}$, $S_{C_{SHRUB,t}}$ for $S_{C_{TREE,t}}$, and $c_{SHRUB,t}$ for $c_{TREE,t}$.

Step 5: Calculate the estimated total shrub biomass carbon stock within the project boundary in year t. With reference to Equation (57), substitute $C_{SHRUB,t}$ for $C_{TREE,t}$, and $c_{SHRUB,t}$ for $c_{TREE,t}$.

Step 6: Calculate the annual change in shrub biomass carbon stock within the project boundary. Shrub biomass changes are assumed to follow a linear growth pattern over the specified time period. With reference to Equation (58), substitute $C_{SHRUB,t}$ for $C_{TREE,t}$, and $dC_{SHRUB(t_1,t_2)}$ for $dC_{TREE(t_1,t_2)}$.

Step 7: Calculate the change in shrub biomass carbon stock within the project boundary for year t (where $t_1 \leq t \leq t_2$) during the verification period. With reference to Equation (59), substitute $dC_{SHRUB(t_1,t_2)}$ for $dC_{TREE(t_1,t_2)}$, and $\Delta C_{SHRUB,t}$ for $\Delta C_{TREE,t}$.

7.7 Appendix 7 Methods for Determining Vine Biomass Carbon Stocks

This Appendix corresponds to Section 6.1.9 of the main text.

Vine biomass is primarily correlated with stem diameter measured at 1.3 m above ground level. Therefore, the biomass equation method can be employed to monitor carbon stocks in the vine biomass carbon pool.

Step 1: Establish subplot k (area ≥ 2 m², 10 m² recommended) within plot p of stratum i. Measure the diameter at 1.3 m above ground level for all vines within the subplot. Apply the biomass equation and use Equation (61) to calculate the vine biomass per unit area in plot p:

$c_{VINE,i,p,t} = \frac{\sum_{k=1}\sum_{j=}[f_{VINE,j}(\Phi) * N_{i,p,k,j,t} * CF_{V,j}]}{\sum_{k=1} A_{VINE,i,p,k,t}} * \frac{1}{100} * \frac{44}{12}$		(61)
Where：		
$c_{VINE,i,p,t}$	=	Average vine carbon stock per unit area in plot p, project carbon stratum i, within the project boundary in year t; $tCO_2e \cdot hm^{-2}$
$f_{VINE,j}(\Phi)$	=	Biomass equation for vine type j as a function of stem diameter at 1.3 m above ground level; g d.m.·branch^{-1}
$N_{i,p,k,j,t}$	=	Number of branches of vine type j in subplot k, plot p, project carbon stratum i, in year t; branch
$CF_{V,j}$	=	Carbon fraction of vine type j; tC·(t d.m.)$^{-1}$
$A_{VINE,i,p,k,t}$	=	Area of subplot k within plot p of the project carbon stratum i in year t; m^2
i	=	1,2,3…… is the project carbon stratum
p	=	1,2,3…… is sample plot in the project carbon stratum i
k	=	1,2,3……subplot within plot p
j	=	1,2,3…… vine type j
t	=	1,2,3……is the number of years since the start of the project; a
$1/100$	=	Conversion factor for converting g·m^{-2} to t·hm^{-2}
44/12	=	Molecular weight ratio of CO_2 to C; dimensionless

Step 2: Calculate the estimated value of the average vine biomass carbon stock per unit area and its variance for carbon stratum i. With reference to Equations (52) and (53), substitute $c_{VINE,i,t}$ for $c_{TREE,i,t}$, $c_{VINE,i,p,t}$ for $c_{TREE,i,p,t}$, and $S_{C_{VINE,i,t}}$ for $S_{C_{TREE,i,t}}$.

Step 3: Calculate the estimated overall mean value (i.e., the estimated average vine biomass carbon stock per unit area) across the entire project area and its variance. With reference to Equations (54) and (55), substitute $c_{VINE,t}$ for $c_{TREE,t}$, $c_{VINE,i,t}$ for $c_{TREE,i,t}$, $S_{C_{VINE,t}}$ for $S_{C_{TREE,t}}$, and $S_{C_{SHRUB,i,t}}$ for $S_{C_{TREE,i,t}}$.

Step 4: Calculate the uncertainty of the estimated average vine biomass carbon stock per unit area within the project boundary. With reference to Equation (56), substitute $u_{c_{VINE,t}}$ for $u_{c_{TREE,t}}$, $S_{C_{VINE,t}}$ for $S_{C_{TREE,t}}$, and $c_{VINE,t}$ for $c_{TREE,t}$.

Step 5: Calculate the estimated total vine biomass carbon stock within the project boundary in year t. With reference to Equation (57), substitute $C_{VINE,t}$ for $C_{TREE,t}$, and $c_{VINE,t}$ for $c_{TREE,t}$.

Step 6: Calculate the annual change in vine biomass carbon stock within the project boundary. Vine biomass changes are assumed to follow a linear growth pattern over the specified time period. With reference to Equation (58), substitute $C_{VINE,t}$ for $C_{TREE,t}$, and $dC_{VINE(t_1,t_2)}$ for $dC_{TREE(t_1,t_2)}$.

Step 7: Calculate the change in vine biomass carbon stock within the project boundary for year t (where $t_1 \leq t \leq t_2$) during the verification period. With reference to Equation (59), substitute $dC_{VINE(t_1,t_2)}$ for $dC_{TREE(t_1,t_2)}$, and $\Delta C_{VINE,t}$ for $\Delta C_{TREE,t}$.

7.8 Appendix8 Method for Determining Dead Wood Biomass Carbon Stock

This Appendix corresponds to Section 6.1.10 of the main text.

7.8.1 Determination of dead wood carbon stock

$c_{DWS,i,p,t} = c_{DWS\_TREE_{i,p,t}} + c_{DWS\_STUMP_{i,p,t}}$			(62)
Where:			
$c_{DWS,i,p,t}$	=	Dead wood carbon stock in plot p of the project carbon stratum i in year t; tCO_2 e	
$c_{DWS\_TREE_{i,p,t}}$	=	Standing dead tree carbon stock in plot p of the project carbon stratum i in year t; tCO_2 e	
$c_{DWS\_STUMP_{i,p,t}}$	=	Standing stump carbon stock in plot p of the project carbon stratum i in year t; tCO_2 e	
i	=	1,2,3……is the project carbon stratum	
p	=	1,2,3…… is sample plot in the project carbon stratum i	
t	=	1,2,3……is the number of years since the start of the project; a	

Among these, dead wood refers to (a) standing dead trees that have only lost their leaves and small branches. (b) standing dead trees that have lost their leaves, small branches and twigs. For the above two types of standing dead trees, first measure the diameter at breast height (DBH) and height of each dead tree. Then, using the method for estimating carbon storage of living trees, calculate the carbon storage per tree. Multiply this value by a discount factor to estimate the carbon storage per dead wood based on the corresponding living tree carbon storage. Finally, sum these estimates to determine the total dead wood carbon storage at the plot level ($C_{DWS\_TREE_{i,p,t}}$).

(a) Standing dead trees that have lost only their leaves and small branches: Dead wood carbon stock equals the carbon stock of entire standing trees multiplied by a discount factor of 0.975;

(b) Standing dead trees that have lost their leaves, small branches and twigs: Dead wood carbon stock equals the carbon stock of entire standing trees multiplied by a discount factor of 0.80.

For standing dead trees or standing stumps that do not fall into the above two categories, the following method can be us to obtain plot carbon storage for standing stumps ($C_{DWS\_STUMP_{i,p,t}}$). Using the machete test method (tap the fallen dead wood with a machete: if the blade bounces back, it is undecayed wood; if the blade penetrates slightly, it is partially decayed wood; if the deadwood splits, it is decayed wood) to classify standing stumps into three density classes: (i) undecayed wood; (ii) partially decayed wood; and (iii) decayed wood. Assign a density discount factor (β) to each density grade. Multiply the basic wood density by this discount factor to obtain the density of the standing stumps.

If the height of a standing stump is less than 4 m, measure the diameter at the midpoint of each stump (D_{MID_STUMP}); if the height of a standing stump is equal to or greater than 4 m, measure the diameter at breast height for each stump.

$D_{MID\_STUMP} = 0.57 * DBH_{STUMP} * (\frac{H_{STUMP}}{H_{STUMP} - 1.3})^{0.80}$			(63)
Where:			
D_{MID_STUMP}	=	Diameter at the midpoint of standing stumps; m	
DBH_{STUMP}	=	Diameter at breast height (1.3m) of standing stumps; m	
H_{STUMP}	=	The height of the standing stump; m	
1.3	=	the height of DBH; m	

The calculation method for standing stump carbon stock is as follows:

$c_{DWS\_STUMP,i,p,t} = \frac{44}{12} * \sum_{j=1} [CF_j * \rho_j * (1 + R_j) * \frac{\Pi}{4} * \sum_{q=1} D^2_{MID\_STUMP,j,q} * H_{STUMP,j,q} * \beta_{j,q})]$			(64)
Where：			
$c_{DWS\_STUMP,i,p,t}$	=	Standing stump carbon stock in plot p of the project carbon stratum i in year *t*; tCO_2e	
CF_j	=	Biomass carbon fraction of tree species *j*; $tC(t\ d.m.)^{-1}$	
ρ_j	=	Wood density of tree species *j*	
R_j	=	The ratio of belowground biomass to aboveground biomass for tree species *j*; dimensionless	
$D_{MID\_STUMP,j,q}$	=	Midpoint diameter of the q standing stump of tree species *j* in plot p of the project carbon stratum i in year *t*; m	
$H_{STUMP,j,q}$	=	Height of the q standing stump of tree species *j* in plot p of the project carbon stratum i in year *t*; m	
$\beta_{j,q}$	=	Density discount factor for the q standing stump of tree species *j* in plot p of the project carbon stratum i in year *t.* Unless project participants have more detailed data, the following default density discount factors apply: (i) undecayed wood = 1.00; (ii) partially decayed wood = 0.80; (iii) decayed wood = 0.45; dimensionless	
i	=	1,2,3……is the project carbon stratum	
j	=	1,2,3……is the tree species *j* in the project carbon stratum *i*	
p	=	1,2,3……is sample plot in the project carbon stratum *i*	
q	=	1,2,3……the q standing stump of tree species *j* in the project carbon stratum *i*	
t	=	1,2,3……is the number of years since the start of the project; a	

7.8.2 Determination of carbon stock in fallen dead wood

The carbon stock of fallen dead wood requires determination and estimation using the transect method. Set up two transects within the plot, with a total length of no less than 100 m, ensuring they intersect perpendicularly at the plot center. Measure the diameter of all fallen dead wood (⩾5 cm) intersecting the transects.

Classify fallen dead wood into three density grades based on decay progression, and assign a discount factor to each grade using the method applied to standing stumps. The carbon stock of fallen dead wood in the sample plot is:

$$c_{DWL,i,p,t} = \frac{44}{12} * \sum_{j=1} CF_j * \rho_j * \frac{\Pi^2}{8L} * \sum_{q=1} D_{j,q}^2 * \beta_{j,q} \quad (65)$$

Where：		
$c_{DWL,i,p,t}$	=	Fallen dead wood carbon stock in plot p of the project carbon stratum i in year t; tCO_2e
CF_j	=	Biomass carbon fraction of tree species j; tC(t d.m.)$^{-1}$
ρ_j	=	Wood density of tree species j
L	=	Total length of sample lines; m
$D_{j,q}$	=	Diameter of the q fallen dead wood of species j intersecting the sample line; cm
$\beta_{j,q}$	=	The density discount factor for the q fallen dead wood of species j intersecting the sample line, based on the factor for standing stump; dimensionless
i	=	1,2,3……is the project carbon stratum
j	=	1,2,3……is the tree species j in the project carbon stratum i
p	=	1,2,3……is sample plot in the project carbon stratum i
q	=	1,2,3……The q standing stump of tree species j in the project carbon stratum i
t	=	1,2,3……is the number of years since the start of the project; a

7.8.3 Calculation of deadwood carbon stock

Step 1: Based on the measurements results from Sections 7.8.1 and 7.8.2, sum up the biomass carbon stocks of standing dead trees and fallen dead wood in the plot to obtain the plot biomass carbon stock of dead wood ($c_{DW,i,p,t}$);

Step 2: Calculate the estimated value and variance of the average carbon storage per unit area of dead wood biomass in the i carbon layer of the project. With reference to Equation (52) and Equation (53), substitute $c_{TREE,i,t}$ for $c_{DW,i,t}$, $c_{TREE,i,p,t}$ for $c_{DW,i,p,t}$, and $S_{c_{TREE,i,t}}$ for $S_{c_{DW,i,t}}$;

Step 3: Calculate the overall average estimate within the project boundary (the estimated average carbon stock of dead wood biomass per unit area) and its variance. With reference to

Equation (54) and Equation (55), substitute $c_{TREE,t}$ for $c_{DW,t}$, $c_{TREE,i,t}$ for $c_{DW,i,t}$, and $S_{C_{TREE,t}}$ with $S_{C_{DW,t}}$, $S_{C_{TREE,i,t}}$ for $S_{C_{DW,i,t}}$;

Step 4: Calculate the uncertainty of the estimated average carbon stock per unit area of dead wood biomass within the project boundary. With reference to Equation (56) , substitute $u_{c_{TREE,t}}$ for $u_{c_{DW,t}}$, $S_{C_{TREE,t}}$ for $S_{C_{DW,t}}$, and $c_{TREE,t}$ for $c_{DW,t}$;

Step 5: Calculate the estimated total biomass carbon storage of dead wood within the project boundary in year *t*. With reference to Equation (57), substitute $C_{TREE,t}$ for $C_{DW,t}$, $c_{TREE,t}$ for $c_{DW,t}$;

Step 6: Calculate the annual change in dead wood biomass carbon storage within the project boundary. Assume that dead wood biomass changes linearly over a given period. With reference to Equation (58), substitute $C_{TREE,t}$ for $C_{DW,t}$ and $dC_{TREE(t_1,t_2)}$ for $dC_{DW(t_1,t_2)}$;

Step 7: Calculate the change in dead wood biomass carbon stock within the project boundary during year *t* of the verification period. With referring to Equation (59), substitute $dC_{TREE(t_1,t_2)}$ for $dC_{DW(t_1,t_2)}$ and $\Delta C_{TREE,t}$ for $\Delta C_{DW,t}$.

7.9 Appendix 9 Methods for Determining Soil Organic Carbon Stock

This Appendix corresponds to Section 6.1.11 of the main text.

Step 1: Establish monitoring plots, taking into account the spatial heterogeneity of the ecosystem, such as tidal gradients and vegetation community differences in mangrove forests. On the basis of *Technical specification for monitoring carbon pool increments in coastal blue with stock-difference method——Part 2: Surface elevation monitoring* (T/CAOE 65-2023), fixed monitoring plots must be established for ground elevation monitoring.

Step 2: Calculate the rate of surface elevation change, bulk density of soil sediments, and carbon content of soil sediments. Within established fixed monitoring plots, use a combination of settlement plates and benchmark rods or other precision leveling methods compliant with regulations to periodically (e.g., annually) measure changes in ground surface elevation relative to fixed benchmarks, thereby determining the rate of surface elevation change use a soil column sampler (such as a Russian peat sampler) to collect primary soil sediment column samples. Divide the collected soil columns into layers according to predetermined depths (eg. 0–15 cm, 15–30 cm, 30–50 cm, 50–100 cm). Use the ring knife method to obtain primary soil samples of a known volume. Dry the soil sample at 105°C until constant weight is achieved. Weigh the dry soil mass. The bulk density of the soil is the ratio of the dry soil mass to the ring-pan volume. This indicator must be measured on-site; estimated values are strictly prohibited. Subsequently, soil samples collected from each layer shall be cleaned of plant roots, stones, and other debris, ground, and sieved. The organic carbon content of the soil samples should be directly determined using an elemental analyzer.

Step 3: Calculate the carbon burial rate in soil sediments using Equation(66):

$CAR_{BSL,t,i} = 10 * SEC_{BSL,t,i} * SBD_{BSL,t,i} * CF_{Soil\_BSL,t,i}$		(66)
Where：		
$CAR_{BSL,t,i}$	=	Carbon burial rate in soil sediments under the project carbon stratum *i* in year *t*; $gC.m^{-2}\cdot a^{-1}$
$SEC_{BSL,t,i}$	=	The rate of change in surface elevation of the project carbon stratum *i* in the *t* year;$mm\cdot a^{-1}$
$SBD_{BSL,t,i}$	=	Soil bulk density of the project carbon stratum *i* in year *t*; $g\cdot cm^{-3}$
$CF_{Soil\_BSL,t,i}$	=	Carbon from soil sediments in the project carbon stratum *i* in year *t*; %
i	=	1,2,3……is the project carbon stratum

t	=	1,2,3……is the number of years since the start of the project; a

If monitoring is difficult, it is advisable to use the rate of surface elevation change in areas surrounding the project or in areas with similar ecological conditions to the project area. Calculate changes in soil organic carbon pools using SEC observational data.

7.10 Appendix 10: Data and Parameters That Do Not Require Monitoring

This Appendix corresponds to Section 6.3 of the main text.

Data/Parameters:	CF_j
Data Unit:	$tC(t\ d.m.)^{-1}$
Used in equations:	(5)、(35)、(64)、(65)
Description:	Carbon content rate of biomass of tree species j
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly published, local, or survey data under similar ecological conditions; (c) Data on mangrove species or species groups at the provincial level (e.g., provincial greenhouse gas inventory); (d) Data on national-level mangrove species or species groups (e.g., National Greenhouse Gas Inventory); (e) Default value: 0.50. *Data source: IPCC LULUCF Good Practice Guidance*
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	$f_{AB,j}(DBH, H, \rho)$
Data Unit:	$t\ d.m \cdot plant^{-1}$
Used in equations:	(6)
Description:	Correlation equations of aboveground biomass of tree species j with diameter at breast height, tree height, and wood density
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly available, local, or survey data from similar ecological conditions; (c) Select from Appendix 11.
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	ρ_j
Data Unit:	g/cm^3
Used in equations:	(6)、(8)、(9)、(64)、(65)
Description:	Wood density of tree species j
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by

	project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly available survey data from local areas or under similar ecological conditions; (c) Data on provincial-level mangrove species or species groups (such as provincial greenhouse gas inventories); (d) Data on nationally important mangrove species or species groups (e.g., national greenhouse gas inventory); (e) Select the default value from the table below: <table><tr><th>Tree species</th><th>ρ_j</th><th>Tree species</th><th>ρ_j</th></tr><tr><td>*Avicennia marina*</td><td>0.62</td><td>*Laguncularia racemosa*</td><td>0.60</td></tr><tr><td>*Bruguiera gymnorhiza*</td><td>0.81</td><td>*Rhizophora apiculata*</td><td>0.87</td></tr><tr><td>*Ceriops tagal*</td><td>0.85</td><td>*Rhizophora mucronata*</td><td>0.83</td></tr><tr><td>*Excoecaria agallocha*</td><td>0.41</td><td>*Sonneratia alba*</td><td>0.47</td></tr><tr><td>*Heritiera littoralis Dryand*</td><td>0.86</td><td>*Sonneratia apetala*</td><td>0.50</td></tr><tr><td>*Heritiera littoralis*</td><td>0.84</td><td>*Xylocarpus granatum*</td><td>0.61</td></tr></table>*Data source: Coastal blue carbon: methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrasses*
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	R_j
Data Unit:	Dimensionless
Used in equations:	(6)、(9)、(10)、(64)
Description:	Ratio of belowground biomass to aboveground biomass of tree species j
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly available, local, or survey data from similar ecological conditions; (c) Data on mangrove species or species groups at the provincial level (e.g., provincial greenhouse gas inventory); (d) Data on national-level mangrove species or species groups (e.g., National Greenhouse Gas Inventory).
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	$f_{AR,j}(h)$
Data Unit:	t d.m.
Used in equations:	(7)
Description:	Allometric growth equation of the respiratory root biomass and

	respiratory root height of tree species *j*
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly available survey data from local areas or under similar ecological conditions; (c) Data on provincial-level mangrove species or species groups (such as provincial greenhouse gas inventories); (d) Data on national-level mangrove species or species groups (e.g., National Greenhouse Gas Inventory).
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	$f_{TB,j}(DBH_j, H_j, \rho_j)$
Data Unit:	t d.m· plant $^{-1}$
Used in equations:	(8)
Description:	Allometric equations relating the total biomass of tree species j to diameter at breast height, tree height, and wood density
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species determined by project participants (transparent and verifiable documentation must be provided to substantiate this); (b) Existing, publicly available survey data from local areas or under similar ecological conditions; (c) Select from Appendix 11.
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	BEF_j
Data Unit:	Dimensionless
Used in equations:	(9)
Description:	Biomass expansion factor of tree species *j*
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly published, local, or survey data under similar ecological conditions; (c) Data on provincial-level mangrove species or species groups (such as provincial greenhouse gas inventories); (d) Data on national-level mangrove species or species groups (e.g., National Greenhouse Gas Inventory); (e) Default value: 3.4. *Data source: IPCC LULUCF Good Practice Guidance*
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	CF_S
Data Unit:	tC·(t d.m.)$^{-1}$
Used in equations:	(13)、(38)
Description:	Carbon content of shrub biomass
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly published, local, or survey data under similar ecological conditions; (c) Data on provincial-level mangrove species or species groups (such as provincial greenhouse gas inventories); (d) Data on national-level mangrove species or species groups (e.g., National Greenhouse Gas Inventory); (e) Default value: 0.47. *Data source: A/R CDM project activities shrub carbon stock and its change estimation tool (V04.2, EB 85)*
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	R_S
Data Unit:	Dimensionless
Used in equations:	(13)、(38)
Description:	Ratio of belowground biomass to aboveground biomass of shrubs
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly published, local, or survey data under similar ecological conditions; (c) Data on provincial-level mangrove species or species groups (such as provincial greenhouse gas inventories); (d) Data on national-level mangrove species or species groups (e.g., National Greenhouse Gas Inventory); (e) Default value: 0.40. *Data source: A/R CDM project activities shrub carbon stock and its change estimation tool (V04.2, EB 85)*
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	BDR_{SF}
Data Unit:	Dimensionless
Used in equations:	(14)
Description:	The ratio of the average aboveground biomass per hectare of shrubs when the shrub cover is 1.0 to the average aboveground biomass per hectare of trees in the project implementation area
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by

	project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly published, local, or survey data under similar ecological conditions; (c) Data on provincial-level mangrove species or species groups (such as provincial greenhouse gas inventories); (d) Data on national-level mangrove species or species groups (e.g., National Greenhouse Gas Inventory); (e) Default value: 0.10. *Data source: A/R CDM project activities shrub carbon stock and its change estimation tool (V04.2, EB 85)*
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	$CF_{v,j}$
Data Unit:	$tC\cdot(t\ d.m.)^{-1}$
Used in equations:	(17)、(41)、(61)
Description:	Carbon content rate of biomass in climbing plants species *j*
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly published, local, or survey data under similar ecological conditions; (c) Default value: 0.46. *Data source: Coastal blue carbon: methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrasses*
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	$f_{VINE}(\Phi)$
Data Unit:	$t\ d.m\cdot plant^{-1}$
Used in equations:	(18)
Description:	Allometric growth equation established based on the relationship between the diameter at 1.3 meters above ground and biomass of lianas
Data Source:	Priority order for data source selection: (a) Locally relevant data determined by project participants (transparent and verifiable information must be provided to demonstrate this); (b) Existing, publicly published, local, or survey data under similar ecological conditions; (c) Calculate using the following default equation: Vine plant biomass $=(D_{1.3})^{2.657} * e^{0.968 * ln(D_{1.3})}$ *Data source: Coastal blue carbon: methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrasses*

Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	DF_{DW}
Data Unit:	%
Used in equations:	(21)、(44)
Description:	The ratio of deadwood carbon storage to live tree biomass carbon storage within the project boundary
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly published, local, or survey data under similar ecological conditions; (c) Default value: 2.55. *Data source: IPCC LULUCF Good Practice Guidance*
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	DV_{BI}
Data Unit:	$tC·hm^{-2}·a^{-1}$
Used in equations:	(24)
Description:	Conservative default factor, annual mangrove biomass carbon stock increment per unit area
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly published, local, or survey data under similar ecological conditions;
Measurement procedures:	Not applicable
Comments:	

Data/Parameters:	DV_{BIO}
Data Unit:	$tC·hm^{-2}$
Used in equations:	(26)
Description:	Conservative default factor, mangrove biomass carbon stock per unit area
Data Source:	Priority order for data source selection: (a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this); (b) Existing, publicly published, local, or survey data under similar ecological conditions; (c) Select the default value from the table below: **Region** / **Carbon storage($tC·hm^{-2}$)** Hainan / 108.35 Guangdong / 70.11

<table>
<tr><td></td><td><table>
<tr><td>Fujian</td><td>25.63</td></tr>
<tr><td>Zhejiang</td><td>1.09</td></tr>
<tr><td>Nationwide</td><td>51.3</td></tr>
</table>
Data source: Jiang Xiaofang. Mangrove Vegetation and Soil Carbon Storage in China and Its Influencing Factors [D]. Xiamen University, 2021.</td></tr>
<tr><td>Measurement procedures:</td><td>Not applicable</td></tr>
<tr><td>Comments:</td><td></td></tr>
</table>

<table>
<tr><td>Data/Parameters:</td><td>$\beta_{LUC,x}$</td></tr>
<tr><td>Data Unit:</td><td>$tC{\cdot}hm^{-2}$</td></tr>
<tr><td>Used in equations:</td><td>(28)</td></tr>
<tr><td>Description:</td><td>Carbon emission coefficient for the conversion of mangrove forest land to land use type x</td></tr>
<tr><td>Data Source:</td><td>Priority order for data source selection:
(a) Parameters of locally relevant tree species measured by project participants (transparent and verifiable evidence must be provided to support this);
(b) Existing, publicly published, local, or survey data under similar ecological conditions;
(c) Data on provincial-level mangrove species or species groups (such as provincial greenhouse gas inventories);
(d) Default value：
<table>
<tr><th>Land use type</th><th>Carbon emission factor($tC{\cdot}hm^{-2}$)</th></tr>
<tr><td>Cropland</td><td>3.732</td></tr>
<tr><td>Grassland</td><td>4.011</td></tr>
<tr><td>Residence</td><td>59.957</td></tr>
<tr><td>Water</td><td>-0.360</td></tr>
<tr><td>Barren</td><td>7.215</td></tr>
</table>
Data source: Lai Li. Study on the Carbon Emission Effects of Land Use in China [D]. Nanjing University, 2010.</td></tr>
<tr><td>Measurement procedures:</td><td>Not applicable</td></tr>
<tr><td>Comments:</td><td></td></tr>
</table>

7.11 Appendix 11 Data and Parameters That Need to Be Monitored

This Appendix corresponds to Section 6.4 of the main text.

Data/Parameters:	A_{BSL_i}
Data Unit:	hm^2
Used in equations:	(6)、(7)、(8)、(9)、(10)、(13)、(18)、(22)、(38)、(45)
Description:	Area of the baseline stratum i
Data Source:	Field measurement
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitored every 5/10 years
QA/QC：	Using the quality assurance and quality control (QA/QC) procedures employed in the National Forest Resource Inventory, the area measurement error does not exceed 5%.
Comments:	In the project scenario, it is denoted by A_{PROJ_i}

Data/Parameters:	DBH_j , H_j
Data Unit:	cm
Used in equations:	(6)、(8)
Description:	The diameter at breast height, diameter at eye level, or ground diameter of tree species j, and tree height
Data Source:	Field measurement
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitor once every 5 years
QA/QC：	Using the quality assurance and quality control (QA/QC) procedures employed in the National Forest Resource Inventory, the area measurement error does not exceed 5%.
Comments:	Tree height can represent the height of the entire forest or other heights; it depends on the definition used in the equation.

Data/Parameters:	h
Data Unit:	cm
Used in equations:	(7)
Description:	Height of respiratory roots of species j
Data Source:	Field measurement
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitor once every 5 years
QA/QC：	Uses the quality assurance and quality control (QA/QC) procedures employed in the National Forest Resource Inventory.
Comments:	

Data/Parameters:	$CC_{SHRUB\_BSL_{i,t}}$
Data Unit:	Dimensionless
Used in equations:	(14)

Description:	Shrub cover of the carbon layer for item i in year t
Data Source:	Field measurement
Measurement steps:	When estimating shrub cover, visual estimation, transect method, and rapid assessment using mirrors are commonly used.
Monitoring frequency:	Monitor once every 5 years
QA/QC：	Uses the quality assurance and quality control (QA/QC) procedures employed in the National Forest Resource Inventory.
Comments:	In the project scenario, it is denoted by $CC_{SHRUB\_PROJ,i,t}$

Data/Parameters:	Φ
Data Unit:	cm
Used in equations:	(18)
Description:	The diameter of the vine plant at 1.3 m above the ground
Data Source:	Field measurement
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitor once every 5 years
QA/QC：	Adopt the quality assurance and quality control (QA/QC) procedures used in the national forest resources survey. If not available, publicly published relevant technical manuals or the procedures described in the IPCC GPG LULUCF 2003 can be used.
Comments:	

Data/Parameters:	A_{BSL}
Data Unit:	hm^2
Used in equations:	(24)、(26)
Description:	Total area within the baseline project boundary
Data Source:	Field measurement
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitor once every 5/10 years
QA/QC：	Using the quality assurance and quality control (QA/QC) procedures employed in the National Forest Resource Survey, the area measurement error does not exceed 5%.
Comments:	In the project scenario, it is denoted by A_{PROJ}

Data/Parameters:	A_p
Data Unit:	hm^2
Used in equations:	(48)
Description:	Fixed plot area
Data Source:	Field measurement and verification
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitored every 5/10 years
QA/QC：	Adopt the quality assurance and quality control (QA/QC) procedures used in the national forest resources survey
Comments:	

Data/Parameters:	A_k
Data Unit:	hm^2
Used in equations:	(60)、(61)
Description:	Fixed plot area
Data Source:	Field measurement and verification
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitored every 5/10 years
QA/QC：	Adopt the quality assurance and quality control (QA/QC) procedures used in the national forest resources survey
Comments:	

Data/Parameters:	$DBH_{STUMP,j,q}$
Data Unit:	m
Used in equations:	(63)
Description:	Chest height diameter
Data Source:	Field measurement
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitored every 5 years
QA/QC：	Adopt the quality assurance and quality control (QA/QC) procedures used in the national forest resources survey
Comments:	

Data/Parameters:	$H_{STUMP,j,q}$
Data Unit:	m
Used in equations:	(63)、(64)
Description:	Height of the dead tree stump
Data Source:	Field measurement
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitored every 5 years
QA/QC：	Adopt the quality assurance and quality control (QA/QC) procedures used in the national forest resources survey
Comments:	

Data/Parameters:	$D_{j,q}$
Data Unit:	cm
Used in equations:	(65)
Description:	Diameter of the fallen deadwood
Data Source:	Field measurement
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitored every 5 years
QA/QC：	Adopt the quality assurance and quality control (QA/QC) procedures used in the national forest resources survey

Comments:	

Data/Parameters:	L
Data Unit:	m
Used in equations:	(65)
Description:	Total sample line length
Data Source:	Field measurement
Measurement steps:	Use the standard operating procedures adopted in national forest resource inventories or forest planning and design surveys
Monitoring frequency:	Monitored every 5 years
QA/QC：	Adopt the quality assurance and quality control (QA/QC) procedures used in the national forest resources survey
Comments:	Tree height can represent the height of the entire forest or other heights; it depends on the definition used in the equation.

Data/Parameters:	SEC
Data Unit:	$mm \cdot a^{-1}$
Used in equations:	(23)、(46)
Description:	Rate of change of ground elevation
Data Source:	Field measurement
Measurement steps:	Adopt the standard operating procedures of the National Forest Resource Inventory or 《Technical Specifications for Monitoring Increases in Coastal Blue Carbon Stocks Based on the Stock Difference Method, Part 2: Surface Elevation Monitoring' (T/CAOE 65-2023)》
Monitoring frequency:	
QA/QC：	Adopt the quality assurance and quality control (QA/QC) procedures used in the national forest resources survey
Comments:	

Data/Parameters:	SBD
Data Unit:	$g \cdot cm^{-3}$
Used in equations:	(23)、(46)
Description:	Soil sediment bulk density
Data Source:	Field measurement
Measurement steps:	Adopt the standard operating procedures of the National Forest Resource Inventory or 《*Technical Specifications for Monitoring Increases in Coastal Blue Carbon Stocks Based on the Stock Difference Method, Part 2: Surface Elevation Monitoring*' (T/CAOE 65-2023)》
Monitoring frequency:	
QA/QC：	Adopt the quality assurance and quality control (QA/QC) procedures used in the national forest resources survey
Comments:	

Data/Parameters:	CF_{Soil_SOC}
Data Unit:	%
Used in equations:	(23)、(46)
Description:	Soil and sediment carbon content
Data Source:	Field measurement
Measurement steps:	Adopt the standard operating procedures of the National Forest Resource Inventory or 《Technical Specifications for Monitoring Increases in Coastal Blue Carbon Stocks Based on the Stock Difference Method, Part 2: Surface Elevation Monitoring' (T/CAOE 65-2023)》
Monitoring frequency:	
QA/QC：	Adopt the quality assurance and quality control (QA/QC) procedures used in the national forest resources survey
Comments:	

7.12 Appendix 12 Reference Table of Biomass Equations for Major Mangrove Species in China

Reference Table of Biomass Equations for Major Mangrove Species in China

No.	Tree species	Allometric Growth Equation (Aboveground Biomass)	Allometric Growth Equation (Belowground Biomass)	Measurement indicators	Carbon conversion factor(%)	Literature basis	Research Area
1	*Avicennia marina*	$lgW_A = 2.092 + 0.529Lg(D^2H)$ (R^2=0.45,n=17)	$LgW_B = 1.361 + 0.615Lg(D^2H)$ (R^2=0.92,n=27)	D, H	41.5	[3]	Futian, Shenzhen, Guangdong
		$W_A = -2.4386 + 0.00801 \times \frac{H}{ln^H} + 1.4796 \times C + 0.0991 \times D_0^2$ (R^2=0.9991)		D_0, H, C		[4]	Daguansha, Beihai, Guangxi
		$W_A = 0.076123 \times (D_0^2H) - 0.222424$ (R^2=0.983)	$W_B = 0.040168 \times (D_0^2H) - 0.12623$ (R^2=0.903)	D_0, H		[5]	Qinzhou Bay, Guangxi
2	*Aegiceras corniculatum*	$LgW_A = 1.496 + 0.465Lg(D^2H)$ (R^2=0.94, n=15)	$LgW_B = 0.967 + 0.303Lg(D^2H)$ (R^2=0.93, n=20)	D, H	43.7	[3]	Futian, Shenzhen, Guangdong
		$W_A = 0.644347 \times (D) - 0.425066$ (R^2=0.912)	$W_B = 0.163242 \times (D) - 0.10423$ (R^2=0.874)	D		[5]	Qinzhou Bay, Guangxi

		$W_A = 0.02039 \times (D_0^2H)^{0.83749}$ (R^2=0.9871)		D_0, H		[6]	Longmen Island, Guangxi
3-4	*Kandelia obovate* *Ceriops tagal*		$W_B = 4.6 * D_{0.1}^{1.136}$	$D_{0.1}$	47.1	[7]	Cangnan, Zhejiang
		$W_A = 0.05698 \times D_0^2 - 0.295595$ (R^2=0.958)	$W_B = 0.009685 * (D_0^2H) + 0.108358$ (R^2=0.928)	D_0, H		[5]	Qinzhou Bay, Guangxi
		$W_A = 10.16 \times D_0^{2.454}$	$W_B = 7.649 \times D_0^{2.064}$			[8]	Futian, Shenzhen, Guangdong
		$LgW_A = 1.053 * lg(D^2H) + 2.814$ (R^2=0.83)	$LgW_B = 0.990 * lg(D^2H) + 2.433$ (R^2=0.95)			[3]	Futian, Shenzhen, Guangdong
5-7	*Rhizophora apiculata*、*Rhizophora stylosa*、*Rhizophora × lamarckii*	$W_A = 2.465\lg(D) - 0.696$ (R^2=0.99, n=6)	$W_B = 1.8601\lg(D) - 0.583$ (R^2=0.92, n=5)	D	49.0	[9]	
8-10	*Bruguiera gymnorrhiza*、*Bruguiera sexangula*、*Bruguiera sexangula var. rhynchopetala*	$W_A = 0.186 \times D^{2.31}$ (R^2=0.99, n=17)	$LgW_B = 1.5541Lg(D^2H) - 0.328$ (R^2=0.99, n=17)	D, H	45.0	[10]	
11-15	*Sonneratia alba*、*Sonneratia caseolaris*、*Sonneratia × hainanensis* *Sonneratia ovata*、*Sonneratia×gulngai*	$W_A = 0.251\rho D^{2.46}$ (ρ =0.475，R^2=0.99, n=15)	$W_B = 0.199\rho^{0.899}D^{2.22}$ (ρ =0.475，R^2=0.99, n=26)	ρ, D	45.0	[11]	
16	*Sonneratia apetala*	$W_A = 0.280(D^2H)^{0.693}$	$W_B = 0.038(D^2H)^{0.759}$	D, H	42.9	[12]	

		$W_A = 0.034 * (D^2H)^{0.966}$ (R^2=0.915)	$W_B = 0.003 * (D^2H)^{1.119}$ (R^2=0.948)	D, H	42.9	[13]	Chaozhou, Guangzhou, Huizhou, Jiangmen, Maoming, Shantou, Shenzhen, Zhanjiang, Zhongshan, Zhuhai in Guangdong
17	*Acrostuchum areum*	$W_A = 0.251\rho D^{2.46}$ (R^2=0.99，n=15)	$W_B = 0.199\rho^{0.899}D^{2.22}$ (R^2=0.99，n=26)	ρ, D	45.0	[11]	
20	*Xylcoarpus granatum*	$W_A = 0.251\rho D^{2.46}$ (R^2=0.99，n=15)	$W_B = 0.199\rho^{0.899}D^{2.22}$ (R^2=0.99，n=26)	ρ, D	45.0	[11]	
21	*Laguncularia racemosa*	$W_A = 0.102D^{2.50}$ (R^2=0.97，n=70)		D	45.0	[14]	
22	*Scyphiphora hydrophyllacea*	$W_A = 0.251\rho D^{2.46}$ (R^2=0.99，n=15)	$W_B = 0.199\rho^{0.899}D^{2.22}$ (R^2=0.99，n=26)	ρ, D	45.0	[11]	
23	*Heritiera littoralis*	$W_A = 0.251\rho D^{2.46}$ (R^2=0.99，n=15)	$W_B = 0.199\rho^{0.899}D^{2.22}$ (R^2=0.99，n=26)	ρ, D	45.0	[11]	

7.13 Appendix13 Method for Constructing a Baseline Identification Step Prediction Model

Method for constructing a baseline identification step prediction model:
taking the FLUS model as an example

7.13.1. Data inventory

The operation of the FLUS model requires two types of core data: historical land use data and driving factor data.

(1) Historical land use data (LUCC)

a. Land use/land cover maps for at least two periods (e.g., 2000, 2010), with data in raster format (*.tif or *.asc). The pixel size, projection coordinate system, and spatial extent must be completely consistent across all years;

b. A clear classification system should be adopted (e.g., arable land, forest land, grassland, water bodies, construction land, unused land). The number of categories should not be too many, usually 6-8 categories are appropriate; otherwise, it will significantly increase model complexity and computation time.

(2) Driver factor data

Select natural geographic and socio-economic variables closely related to land use changes. All driving factors must have the same projected coordinate system, spatial extent, and pixel size as the land use data.

a. Physical and geographical factors:

Elevation;

Slope;

Slope direction;

Distance from the project area to the river/water body;

The distance from the project area to the coastline;

Soil type;

Temperature;

Precipitation;

Evapotranspiration;

b. Socio-economic and locational factors:

Distance from the project area to the city center (downtown, town government);

Distance from the project area to major transportation routes (expressways, national highways, railways);

Population density distribution map of the project area;

Project area GDP distribution map.

Distance from the project area to the commercial center and schools;

Note: All continuous driver factor data need to be standardized (e.g., normalized to the range 0-1) before being input into the model to eliminate the impact of different units.

(3) Auxiliary data (used for setting restricted areas and future scenarios)

a. Restricted area data

Ecological protection red lines, permanent basic farmland, and prohibited construction zones in territorial spatial planning. They are usually made into binary maps (0 indicates conversion is prohibited, 1 indicates conversion is allowed);

b. Future scenario setting data

Climate, population, and GDP forecast data under different SSPs (Shared Socioeconomic Pathways) or RCPs (Representative Concentration Pathways), used to construct different development scenarios.

7.13.2. Data source

(1) Land use data:

a. Global scope

ESA CCI land cover：Provides annual global data from 1992 to the present, with a resolution of 30 m. https://www.esa-landcover-cci.org/

MODIS land cover (MCD12Q1)：Provide annual data from 2001 to the present, with a resolution of 500 m. https://www.earthdata.nasa.gov/data/catalog/lpcloud-mcd12q1-006

b. Across China

Resource and Environmental Science and Data Center of the Chinese Academy of Sciences: Provides multi-period (every 5 years) China land use datasets with 1km and 100m resolution. This is the most commonly used and high-quality Chinese data source. https://www.resdc.cn/

FROM-GLC：Global 30m resolution land cover data produced by Tsinghua University. https://data.ess.tsinghua.edu.cn/

(2) Natural geographic factor data

Elevation data:

SRTM：Global data with 90m and 30m resolution. https://srtm.csi.carnegiescience.edu/

ALOS World 3D：30m resolution global data. https://www.eorc.jaxa.jp/ALOS/en/aw3d30/

Meteorological data:

WorldClim：Global high-resolution climate data. https://www.worldclim.org/

(3) Socio-economic factor data:

WorldPop：High-resolution global population spatial distribution data. https://www.worldpop.org/

NPP-VIIRS：A new generation of nighttime light data (could be used as a proxy variable for the level of economic development). https://eogdata.mines.edu/products/vnl/

POI (Point of Interest) data: obtained from open map platforms (such as OpenStreetMap, Amap API, Baidu Map API), used to calculate the distance from the project area to constraint factors (such as core protected areas, water bodies, etc.).

7.13.3. Operating steps

(1) Data preparation and preprocessing

a. Determine the study area and delineate the boundaries

Process all land use data and driving factor data into a completely consistent raster format (.tif), cell size, projection, and extent;

b. Prepare restricted area documents, that is, determine the project area boundaries.

(2) Model training and accuracy validation

a. Build a predictive model

In the FLUS software, take the earlier land use map (such as 2000) as 'Period T1' and the later map (such as 2010) as 'Period T2';

b. Input driving factor

Load all processed driving factor layers;

c. Train ANN (Artificial Neural Network)

To obtain the development probability of each land use type under the influence of different driving factors, the model will randomly select a large number of sample points to train the neural network;

d. Set training parameters

Variables such as the number of iterations and the number of neurons in the hidden layer need to be adjusted according to the actual situation. It is generally believed that a single-hidden-layer neural network can achieve the best prediction performance after 1,000 iterations;

e. Verify simulation accuracy:

Use the trained ANN to simulate land use in 2010 (with 2000 as the base year), and compare the simulation results with the actual land use map of 2010. Calculate the Kappa factor to assess the simulation accuracy. Generally, a Kappa > 0.8 is considered acceptable model performance. If the accuracy is poor, it is necessary to check the selection of driving factors or the quality of the data;

(3) Future scenario prediction

a. Set future requirements

It is necessary to determine the total demand (area) for various types of land use by the target year (e.g., 2030). The methods for obtaining this information can include urban planning objectives, extrapolation of historical trends, Markov chain prediction, etc;

b. Set cost and neighborhood weight parameters

Cost matrix: defines the difficulty of converting between different land types (for example, it is easy to convert farmland to construction land, but extremely difficult to convert construction land back to farmland);

Neighborhood weight: Reflects the spatial clustering effect of each land-use type (typically, construction land has a high neighborhood weight, meaning it tends to expand around existing towns);

c. Run CA (Cellular Automata) simulation

Using the most recent land use data (e.g., 2010) as the baseline, import the probability maps calculated by the trained ANN, input future demand, cost matrix, and neighborhood weights, and set the number of iterations ((target year - baseline year) × iterations per year). For example, if forecasting 20 years with 10 iterations per year, the total number of iterations would be 200);

d. Output results

Obtain the land use simulation map for the target year;

(4) Result analysis and post-processing

a. Visualization

In ArcGIS, map the simulation results to visually display future spatial patterns;

b. Change analysis

Calculate the changes in area for different types in various regions, as well as the hotspots of spatial changes;

c. Set multiple scenarios

By changing the 'future demand' or 'restricted areas' (such as scenarios for ecological protection, urban expansion, etc.), repeat step (3) to conduct multi-scenario simulation and comparative analysis;

(5) Model selection

If the collected data is sufficient to support the construction of multiple models, the model with the highest accuracy should be selected according to step (2).

References

[1] Guidelines for Investment Estimation of Ecological Conservation and Restoration Projects in Key Areas. National Forestry and Grassland Administration. 2024.

[2] Garrett MG, Candela SG, Rod B, Miguel CJ, Daniel AF, Jennifer H, Dane HK, Solina T, Thomas AW, Jonah B. Implementation costs of restoring global mangrove forests [J]. One Earth, 2025, 8 (7): 101342.

[3] Tam N, Wong Y, Lan C, Chen G. Community structure and standing crop biomass of a mangrove forest in Futian Nature Reserve, Shenzhen, China[J]. Hydrobiologia, 1995, 295(1-3): 193-201.

[4] Fan H, Yin Y, Lao L. Correlation Analysis of Aboveground Biomass of Coastal Mangrove *Avicennia marina* in Guangxi [J] Journal of the Guangxi Academy of Sciences, 1993, 9 (2): 25-30.

[5] He Q, Zheng W, Huang, Liu X, Shen W, He F. Carbon storage and distribution of mangroves at Qinzhou bay [J] Journal of Central South University of Forestry, 2017, 37 (11): 121-126.

[6] Ning S, Jiang Y, Deng Z. A preliminary study on biomass of *Aegicer as corniculatum* natural forest in longmen islets of Guangxi [J]. Acta Phytoecologica Sinica, 1996, 20 (1): 57-64.

[7] Jin C, Wang J, Zheng J, Chen Q, Li J, Lu X. An assessment method of *Kandelia obovata* population biomass [J] Acta Ecologica Sinica, 2012, 32(11): 3414-3422.

[8] Lunstrum A, Chen L. Soil carbon stocks and accumulation in young mangrove forests [J]. Soil Biology & Biochemistry, 2014, 75: 223-232.

[9] Comley BW, McGuinness KA. Above- and below-ground biomass, and allometry, of four common northern Australian mangroves [J]. Australian Journal of Botany, 2005, 53(5): 431-436.

[10] Clough BF, Scott K. Allometric relationships for estimating above-ground biomass in six mangrove species[J]. Forest Ecology and Management. 1989, 27(2): 117-127.

[11] Komiyama A, Poungparn S, Kato S. Common allometric equations for estimating the tree weight of mangroves [J]. Journal of Tropical Ecology, 2005, 21(4): 471-477.

[12] Liu, H, Ren H, Hui D, Wang W, Liao B, Cao Q. Carbon stocks and potential carbon storage in the mangrove forests of China[J]. Journal of Environmental Management, 2014, 133: 86-93.

[13] Hu Y, Xu Y, Xue Y. Studies on carbon storages of *Sonneratia apetala* foret vegetation and soil in Guangdong Province[J]. Journal of South China Agricultural University, 2019, 40 (6): 95-103

[14] Fromard F, Puig H, Mougin E, Marty G, Betoulle JL, Cadamuro L. Structure, aboveground biomass and dynamics of mangrove ecosystems: new data from French Guiana [J]. Oecologia, 1998, 115: 39-53.