Carbontribe Methodology

Forest Land Projects

1. Introduction

Since the mid-20th century, global forests have faced significant declines due to deforestation, land-use changes, and other human-driven activities. These disturbances have resulted in the loss of vast forested areas, diminishing their ability to act as natural carbon sinks and exacerbating the challenges of climate change. Efforts to reverse these trends, particularly through afforestation, offer a practical and impactful strategy for restoring degraded ecosystems and enhancing their carbon sequestration potential.

The success of afforestation projects depends on the careful selection of species, restoration techniques, and the re-establishment of ecological conditions conducive to forest growth. This document presents a comprehensive methodology for our afforestation-based projects, providing a systematic approach to quantifying and verifying CO_2 sequestration. It is designed to guide the restoration and conservation of forest ecosystems, addressing the degradation caused by human activity.

Forests are among the most significant natural carbon reservoirs, storing substantial amounts of carbon in their biomass and soils. Given their critical role in climate regulation, precise and scientifically validated methodologies are essential to ensure the accuracy and credibility of carbon sequestration estimates from afforestation projects.

The methodologies outlined in this document draw upon the IPCC 2006 Guidelines for National Greenhouse Gas Inventories and the 2019 Refinement, which provide internationally recognized frameworks for forest carbon accounting. Building upon these principles, this approach incorporates innovative tools and techniques tailored to the specific requirements of afforestation. It also aligns with the Core Carbon Principles (CCPs) established by the Integrity Council for the Voluntary Carbon Market (ICVCM), ensuring that carbon credits are real, additional, permanent, and independently verified. By combining robust scientific methods with adaptive, technology-driven solutions, this methodology ensures reliable carbon accounting while promoting global best practices in climate mitigation and forest ecosystem restoration.

2. Project design

This section presents the foundational framework for developing and implementing Carbontribe's forest projects, ensuring alignment with our common methodology and adherence to best practices. Chapter 2.2 will thereafter focus on the two first steps of the Carbontribe project cycle; conceptualization and onboarding as well as feasibility and design.

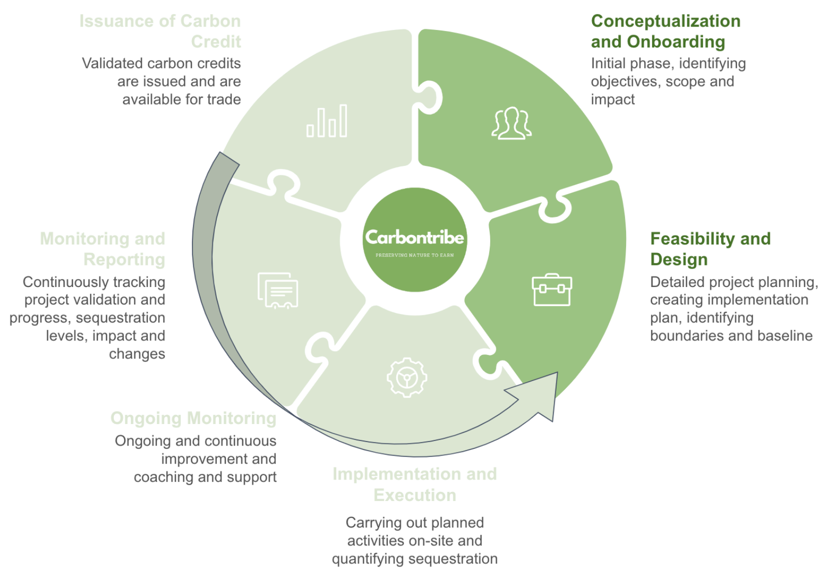

Figure 2: Initial Phases of the Project Cycle

The initial section of this chapter focuses on defining the project's scope and objectives, while the latter part provides a detailed overview of project planning, including the identification of project boundaries and baseline estimation.

To ensure a structured onboarding process, potential project participants will complete a comprehensive form addressing each stage of the process described below (form available in a separate document). This step-by-step engagement facilitates alignment with our methodology, ensures adherence to established best practices, and sets the foundation for achieving the project's objectives effectively.

2.1 Project Description

2.1.1 Project Scope

For this methodology Carbontribe focuses on afforestation projects within forest ecosystems, ensuring precise and transparent greenhouse gas (GHG) removal estimations. By focusing on the establishment of forests on previously barren or non-forested lands, this approach ensures precise carbon sequestration measurements and supports ecosystem enhancement through deliberate and well-documented afforestation efforts.

Projects related to reforestation, revegetation, or activities under Reducing Emissions from Deforestation and Forest Degradation (REDD) are excluded from this methodology. While these projects are vital to global climate and conservation goals, they involve different objectives, challenges, and accounting methods. To ensure clarity and rigor, any future expansion to include reforestation, revegetation, or REDD activities will be addressed through separate, dedicated methodologies tailored to their specific needs.

Projects applying under this methodology must provide clear evidence of afforestation activities, supported by detailed project plans, historical land-use data, and satellite imagery. These requirements ensure that project sites are accurately identified as previously barren or non-forested lands, maintaining the integrity and credibility of GHG removal estimations.

2.1.2 Purpose and Objectives

The project needs to define its overarching goal, which includes carbon sequestration, the restoration or enhancement of forest ecosystems, and the delivery of biodiversity and community co-benefits. This should encompass the specific environmental outcomes aimed for and these objectives should be clear, measurable, and aligned with the overall sustainability goals of the project.

2.1.3 Project Boundaries

Carbon Pools and GHG Sources: The project needs to define the carbon pools and GHG sources associated with both the project and baseline scenarios. These include above-ground biomass, below-ground biomass, soil organic carbon, and dead organic matter. Developers are required to provide detailed data on these carbon pools, along with methods for measuring and monitoring carbon stocks.

Geographical Boundaries: The geographical boundaries define the physical area in which the forest restoration or protection activities will take place. It is essential to clearly delineate these boundaries to avoid overlap with other carbon offset projects. Carbontribe then cross-check and overlay the new project boundaries onto the existing repository database to detect any spatial overlap or inconsistencies

Carbontribe will validate the project area and analyse land cover usages. For that, project developers are required to provide geographic information in a standardized format. This information must be submitted in the form of a KML file or a text file with an array of geographic coordinates. Below are the specific requirements and conditions for this submission:

Submission Format

1. **KML File**:
    - The KML (Keyhole Markup Language) file must accurately delineate the project boundary.
    - It must include a single, contiguous polygon or set of polygons representing the entire project area.

    - The KML file must be formatted to be compatible with common GIS (Geographic Information Systems) and GPS software such as Google Earth, ArcGIS, and QGIS.
2. **Array of Coordinates**:
    - If a KML file is not submitted, the project boundary may alternatively be defined by an array of geographic coordinates (latitude and longitude) separated by commas. Each row has to be separated by a new line.
    - The coordinates must be listed sequentially to form a closed loop that represents the boundary.

File Specifications

1. **Coordinate System**:
    - All coordinates must be provided in the WGS84 datum (EPSG:4326).
2. **Boundary Precision**:
    - Ensure the precision of the boundary coordinates is sufficient to prevent ambiguity, with at least six decimal places (e.g., 37.774929, -122.419416).
3. **File Integrity**:
    - The file must be free of errors and validate against standard KML or GIS file validators.

2.1.4 Stakeholder Engagement

Stakeholder engagement is essential for ensuring the success and sustainability of forest restoration projects, as it fosters collaboration, builds trust, and ensures that local needs and priorities are met. To achieve this, projects should actively involve local communities, governments, environmental organizations, and other relevant stakeholders throughout all stages of the process.

In areas where Indigenous peoples and local communities are impacted, projects must adhere to Free, Prior, and Informed Consent (FPIC) principles. This involves early engagement, clear communication of project details, and securing documented consent before implementation. Compliance measures, records of consultations, and participatory decision-making processes—are required to ensure alignment with community rights and environmental standards, particularly in high-risk regions.

To maintain accountability, all relevant documentation, including stakeholder engagement records, FPIC agreements (where applicable), and evidence of compliance, must be submitted as part of the application process. This ensures that projects meet ethical and legal standards while fostering long-term community support and environmental impact.

2.2 Baseline Description

The baseline represents the "before" scenario, reflecting the state of the ecosystem prior to any afforestation activities. Since this methodology is dedicated exclusively to afforestation, only areas where new forests are being established are considered. In such cases, the baseline carbon stock is assumed to be zero, as these areas were previously barren or not historically covered by forests. This baseline serves as the critical reference point for calculating the net carbon benefits of the project and ensuring additionality—demonstrating that carbon sequestration would not have occurred without the afforestation intervention. If methodologies for other activities such as reforestation or revegetation are introduced in the future, their baselines will be developed separately to account for their unique characteristics.

To ensure accurate carbon accounting, any existing forest areas within the proposed project boundary must be excluded. Developers are responsible for identifying and excluding these areas during project planning and submission to ensure the focus remains solely on the establishment or restoration of new forest ecosystems.

2.2.1 Baseline Validation

To validate that the area was non-forested at the baseline period, the following steps are required:

1. **Official Certification**
   Project developers must provide a certificate from the landowner or relevant government authority confirming that the land was not classified as forested during the baseline period. Therefore, project areas must not meet the forest classification criteria as defined by the national forest definition of the host country. Additionally, the land must not consist of natural vegetation types other than forests at the start of project activities. Eligible land types include grasslands, shrublands, degraded lands and deforested land (if permanently converted).

2. **Carbontribe Land Cover Analysis**
   If an official certificate is unavailable, Carbontribe will conduct a land cover analysis using historical remote sensing data. This analysis will verify land use and vegetation cover up to 5 years prior to the baseline period, ensuring that the area meets the eligibility criteria for our projects.

2.3 Additionality

In forest restoration projects, additionality ensures that carbon credits represent real, measurable, and surplus carbon removals that would not have occurred without the project. To demonstrate additionality, the activities carried out must be clearly distinct from the baseline scenario, which assumes zero carbon sequestration for new forest areas. The project must result in outcomes—such as the establishment or restoration of forest ecosystems—that would not have happened without the intervention.

To establish additionality, the following key tasks must be undertaken:

1. **Clear Description of Activities**: Projects must detail the specific activities they are implementing, such as planting new forests, restoring hydrological conditions, or improving soil retention. These activities should be outlined with clear timelines and objectives that highlight their role in establishing or restoring forest ecosystems.
2. **Comparison with Previous Land Use**: The project must demonstrate how these activities differ from prior land use practices, whether it be agriculture, development, or degraded land that would otherwise not regenerate. Evidence of past land use, such as historical records or satellite imagery, should be provided to show that the land would not naturally revert to forests without intervention.
3. **Deforestation Assessment**: Projects must assess if any deforestation has taken place within the last five years in the proposed area. Historical satellite imagery can be used to verify whether the land has been cleared, supporting the case that the restoration activities are reversing prior degradation and facilitating carbon sequestration.

By demonstrating these factors, projects can validate their additionality, ensuring that the carbon sequestration achieved is directly attributable to the restoration activities, and would not have occurred in the absence of the project.

2.4 Leakage Analysis

In addressing leakage in forest restoration projects, Carbontribe emphasizes the importance of minimizing the displacement of carbon emissions from the project area to surrounding regions, as this can undermine the carbon sequestration benefits. Leakage occurs when activities within the project area inadvertently lead to environmental degradation or deforestation in adjacent or nearby areas, offsetting the intended carbon removal.

To minimize leakage, Carbontribe ensures careful project design by clearly defining project boundaries and conducting thorough baseline assessments. This helps identify potential risks of emissions displacement before the project begins. In addition, implementing buffer zones around the restoration area and monitoring surrounding ecosystems for any signs of degradation are essential measures. This approach helps ensure that restoration efforts do not cause negative environmental impacts outside the project’s designated area.

Real-time monitoring through satellite imagery is employed to track the growth and health of the restored forests and detect any unauthorized activities or changes in land use. This technology also helps verify that carbon sequestration is happening as planned, with transparent tracking of the project's carbon removal.

By combining careful planning with continuous monitoring, Carbontribe ensures that the carbon sequestration benefits of forest restoration projects are genuine and additional, minimizing the risk of leakage and ensuring that the carbon credits generated reflect real, lasting carbon removals rather than simply shifting emissions elsewhere.

2.5 Monitoring and Verification

Monitoring and verification are essential elements of Carbontribe's methodology, ensuring the integrity of carbon sequestration outcomes and the credibility of carbon credits generated. These processes are aligned with international best practices and scientific guidelines, such as those outlined in the IPCC 2006 Guidelines and the 2019 Refinement.

2.5.1 Monitoring

Carbontribe's monitoring framework focuses on systematic data collection to track carbon sequestration, ecological health, and compliance with baseline and leakage parameters. This includes quantifying changes in above-ground and below-ground biomass, soil organic carbon levels, and other project-specific indicators.

To enhance accuracy, Carbontribe integrates on-the-ground field measurements with advanced technological tools such as remote sensing, geographic information systems (GIS), and computer vision models. These tools enable precise tracking and allow for early detection of deviations from projected outcomes, ensuring adaptive management throughout the project lifecycle. If the Tier 1 approach is chosen, Carbontribe will manage the monitoring process. However, if a higher-tier approach is selected or necessary, the applicant will assume responsibility for overseeing the monitoring

2.5.2 Verification

Verification involves an independent assessment by third-party auditors to validate the monitoring data and ensure compliance with established methodologies. This step confirms that the carbon sequestration outcomes are measurable, verifiable, and accurately reported. By relying on independent verification, Carbontribe maintains transparency and credibility in its carbon crediting processes.

By combining rigorous monitoring with third-party verification, Carbontribe ensures that its projects deliver quantifiable climate and environmental benefits. This continuous feedback loop also facilitates improvements in project implementation, fostering innovation and reinforcing our commitment to reliable, impactful carbon market participation.

3. Quantification of Estimated Removals

This chapter focuses on Step 3 of the project cycle, implementing the project and quantifying carbon sequestration to measure the direct impact. This Carbontribe methodology project follows the guidelines set forth in the IPCC 2006 and 2019 Refinement ensuring compliance with globally recognized standards for carbon accounting in forest ecosystems.
The IPCC framework offers multiple "Tiers" for calculating carbon sequestration, depending on the data available and the precision needed. Tier 1 represents the most basic level, relying on default values and general models for carbon estimation. The calculations presented in this methodology use Tier 1 default values as the starting point. However, if more appropriate, project-specific data becomes available, Carbontribe will adjust the calculations to apply higher Tiers (Tier 2 or Tier 3), which provide more localized and precise carbon estimates.

This approach allows Carbontribe to ensure that calculations remain both accurate and feasible, depending on the data at hand, while still adhering to the best practices outlined by the IPCC. The following sections describe the calculations for annual carbon sequestration, detailing the specific components that contribute to the overall sequestration estimate.

3.1 Process Flow

Accurately quantifying forest coverage and estimating CO_2 sequestration potential is crucial for understanding the role of forests in mitigating climate change. Carbontribe leverages computer vision models and remote sensing technologies to classify forest and non-forest areas, monitor critical forest parameters, and estimate annual carbon sequestration rates. This methodology integrates high-resolution satellite imagery, machine learning algorithms, and ecological equations to provide a comprehensive, scalable solution for forest monitoring and carbon accounting.

Step 1: Data Acquisition and Preprocessing

- Satellite imagery data is collected from various sources such as remote sensing platforms.
- The collected data undergo preprocessing, including noise reduction, radiometric correction, atmospheric correction, and geographic alignment, to ensure compatibility with the computer vision models.

Step 2: Forest Classification Using Computer Vision

- Our computer vision model is trained to classify regions as forest or non-forest at pixel level. Training data includes labeled examples of both categories.
- The model processes high-resolution satellite images to identify forested areas based on spectral, textural, and structural features.
- The output is a classified map highlighting forest and non-forest regions at pixel-level.

Step 3: Monitoring Key Forest Parameters

- For areas classified as forest, the monitoring process aligns with IPCC guidelines to estimate forest biomass and carbon stocks accurately. More detailed information about what parameters and how exactly we conduct the monitoring can be found in the following chapters.
- Wherever possible, further literature reviews will be conducted to obtain detailed information such as country-specific factors, forest type-specific allometric equations, and regional emission factors. This ensures that monitoring results are both scientifically robust and tailored to local ecological contexts.
- These parameters are monitored over time at the specified frequency to track changes and trends in forest health and growth.

Step 4: CO_2 Sequestration Estimation

- Using the monitored parameters, relevant equations or biomass models are applied to estimate carbon storage.

Step 5: Blockchain Storage

- All relevant data, including forest classification outputs, monitored parameters, and CO_2 sequestration estimates, are securely stored on a decentralized blockchain platform.
- Data links, metadata, and timestamps are recorded to ensure traceability and tamper-proof documentation.

Step 6: Digital Asset Creation:

- A digital asset in the form of a Non-Fungible Token (NFT) is created to represent the carbon sequestration results for a specific geographic area and time period.
- The NFT includes embedded data or links to external datasets, including:
  - Detected forest areas
  - Parameter estimates and methods
  - Scientific equations and values used in the calculations
  - Documentation on compliance with IPCC methodologies and any country-specific factors
- The blockchain-stored data and NFT serve as a transparent and auditable foundation for issuing carbon credits.
- This process ensures that credits are backed by scientifically verified data, reducing the risk of fraudulent claims.

3.2 Annual Carbon Sequestration

The total CO_2 removed by the project per year is calculated as:

$$CO_2\ Removed\ (tCO_2/year) = CO_2\ from\ AGB + CO_2\ from\ BGB + CO_2\ from\ DOM + CO_2\ from\ SOC - Leakage\ (tCO_2/year) - Project\ Emission\ (tCO_2/year)$$

In this equation:

- **CO_2 from AGB**: Carbon dioxide removed by above-ground biomass (trees, plants, etc.)
- **CO_2 from BGB**: Carbon dioxide removed by below-ground biomass (roots and soil-bound organic matter)
- **CO_2 from DOM**: Carbon dioxide stored in dead organic matter, like decaying plant material
- **CO_2 from SOC**: Carbon dioxide sequestered in soil organic carbon (carbon stored in the soil)

Each of these components is multiplied by a **C to CO_2 factor** to convert carbon (C) into CO_2 equivalents.

Finally, **Leakage** refers to any emissions that occur outside the project area as a result of the project's activities, while **Project Emission** includes any emissions generated by the project itself, such as from energy use or land preparation. These values are subtracted from the total carbon sequestration to reflect the net impact of the project.

3.3 CO_2 Removal from Above-ground biomass (AGB)

$$CO_2\ by\ AGB\ (tCO_2/year)\ =\ AGB\ Sequestration\ Rate\ (tC/ha/year) \times Area\ (ha) \times C\ to\ CO_2\ \ factor$$

The Above-Ground Biomass (AGB) Sequestration Rate (tC/ha/year) represents the annual amount of carbon stored in the above-ground biomass of mangrove trees per hectare. This metric is expressed in metric tons of carbon (tC) sequestered per hectare annually and serves as a key indicator of how effectively vegetation absorbs atmospheric carbon dioxide (CO_2) and incorporates it into its biomass.
The IPCC 2019 Refinement (Table 4.9 & 4.10) provides default values for AGB sequestration rates categorized by climate domain, ecological zone, continent, status/condition and/or species. These sources provide Tier 1 default values, which are widely accepted for general use when more detailed, localized data is unavailable.

To ensure accuracy in the Above-ground biomass (AGB) sequestration rates used:

1. **Tier 1 Approach**: Default rates provided by the IPCC are used in cases where site-specific data is not available.
2. **Refined Approaches (Tier 2 or 3):** When available, project-specific data or values derived from peer-reviewed studies are prioritized. These may be obtained through recent scientific literature or direct field measurements.

This approach balances the use of standardized guidelines with the integration of site-specific data to enhance the credibility and accuracy of carbon accounting in mangrove afforestation and reforestation projects.

3.4 CO_2 Removal from Below-ground biomass (BGB)

The below-ground biomass (BGB) represents the roots and other subterranean components of trees that store carbon. CO_2 removal from BGB refers to the carbon dioxide absorbed from the atmosphere and subsequently stored in these below-ground components as part of the tree's natural growth and carbon cycle processes and is calculated with the following equation:

$$CO_2\ by\ BGB\ (tCO_2/year) = BGB\ to\ AGB\ ratio \times CO_2\ by\ AGB\ (tCO_2/year)$$

The BGB to AGB ratio is a proportion that indicates how much carbon is stored below ground for every unit of carbon stored above ground. This ratio varies by species, ecological zone, climate, and environmental factors. The IPCC 2019 Refinement (table 4.4) offers default ratios categorized by region and species, serving as a Tier 1 default method. If site-specific data or species-specific studies are available (Tier 2 or 3 approaches), these should be applied for greater accuracy.

This accurate estimation of below-ground biomass (BGB) sequestration rates is critical for quantifying carbon storage in mangrove ecosystems. To achieve this:

- **Tier 1 Approach:** Default ratios of BGB to AGB provided in global standards, such as the IPCC 2019 Refinement (table 4.4), are applied when specific site data is unavailable. These defaults ensure consistency and a reliable starting point.
- **Refined Approaches (Tier 2 or 3):** Site-specific measurements or species-based ratios derived from recent scientific literature are prioritized when available. Regionally-relevant BGB-to-AGB ratios from peer-reviewed studies or field data, reflecting actual sequestration conditions.

3.5 CO_2 Removal from Dead Organic Matter (DOM)

As shown in the overall equation, one of the components contributing to CO_2 removal is Dead Organic Matter (DOM). Dead wood pools contain carbon in coarse woody debris, dead coarse roots, standing dead trees, and other dead material not included in the litter or soil carbon pools. These materials capture and store carbon that was initially absorbed from the atmosphere during the growth of the plants. Over time, as this organic matter decomposes, it continues to play a role in carbon cycling within the ecosystem. The corresponding equation for calculating the CO_2 removal from DOM is as follows:

$$CO_2\ by\ DOM\ (tCO_2/year) = (ChangeCarbonInput - ChangeCarbonDecay) \times C\ to\ CO_2\ factor$$

Estimating the size and dynamics of the dead wood pool poses many practical limitations, particularly related to field measurements. According to the IPCC 2006, the uncertainties associated with estimates of the rate of transfer from the DW pool to the litter and soil pools, and emissions to the atmosphere are generally high. The amount of dead wood is highly variable between stands, both in managed and unmanaged lands. Amounts of dead wood depend on the time since last disturbance, the type of the last disturbance, losses during disturbances, the amount of biomass input (mortality) at the time of the disturbance, natural mortality rates, decay rates, and management
To overcome this practical difficulty, Carbontribe adopts a conservative approach and assumes no net changes in carbon stock within DOM pools, as the straightforward input-output equations employed in these methods are inadequate for reflecting the dynamics of DOM pools

3.6 CO_2 removal from Soil Organic Carbon (SOC)

Soil organic carbon (SOC) is an essential component of the carbon sequestration process in forest ecosystems. SOC is the carbon stored in the soil as a result of decaying organic matter, plant roots, and other biological processes that convert atmospheric CO_2 into stable organic compounds over time. This carbon storage occurs through the accumulation of organic material in the soil, contributing to long-term carbon sequestration. The calculation for annual CO_2 removal from SOC is:

$$CO_2\ by\ SOC\ (tCO_2/year) = SOC\ Sequestration\ Rate\ (tC/ha/year) \times Area\ (ha) \times C\ to\ CO_2\ factor$$

Despite growing research on the effects of forest types, management practices, and disturbances on soil organic carbon, findings remain site- and study-specific, making broad generalizations difficult. Current evidence is inconclusive on the magnitude and direction of carbon stock changes in mineral forest soils. As a result, Carbontribe's Tier 1 methods assume no change in forest soil C stocks due to management, as the scientific basis is insufficient to establish default emission factors. Studies show effects of forest management on soil C stocks are variable and sometimes contradictory, and in Tier 1, changes in mineral soil C are considered zero if using more detailed activity data approaches. This is consistent with the broader principles outlined in IPCC 2019, Volume 4, Chapter 4.

3.7 Project Emissions

Project emissions refer to the greenhouse gases emitted during activities like land preparation, planting, and maintenance in reforestation projects. For forest restoration, project emissions are assumed to be zero, as the activities involved are generally low-impact, such as planting native species and minimizing land disturbance. Forest restoration activities typically focus on ecosystem recovery without causing significant emissions, which supports the assumption of negligible project emissions.

However, if significant emissions are expected due to activities such as land clearing or infrastructure development, IPCC guidelines will be followed to accurately estimate these emissions. These guidelines provide methods for calculating emissions from machinery use, transportation, and other land management activities, ensuring accurate carbon accounting in such cases.

3.8 Leakage

Leakage refers to the unintended displacement of carbon emissions or removal from the project area due to restoration activities. In the case of forest restoration, leakage is generally minimal, but it can vary depending on the specific activities and surrounding land-use dynamics. Based on the *IPCC 2006 and IPCC 2019 Refinement* and common carbon accounting practices, the following approach is used:

- **Tier 1**: Leakage is assumed to be negligible, as forest restoration typically involves low-impact activities like planting native species and avoiding land-use changes that could lead to increased emissions. This approach follows the IPCC guidelines that suggest leakage is not a significant risk in such low-disturbance activities.
- **Tier 2**: Leakage is still assumed to be negligible, but active monitoring of the surrounding area is implemented. Through the use of a computer vision model, Carbontribe tracks any changes in the landscape around the restoration site. This monitoring helps identify and mitigate potential leakage risks, ensuring that no unintended deforestation or land-use changes occur nearby.
- **Tier 3**: In cases where higher leakage risks are identified, such as potential emissions from nearby deforestation or infrastructure development, detailed calculations and analysis are performed. IPCC guidelines will be followed to assess and quantify potential emissions displacement, ensuring that leakage is accurately accounted for.

3.8.1 Calculations of Leakage

For projects with a higher risk of leakage—such as those displacing agricultural activities, timber harvesting, or livestock grazing— leakage must be accounted for in the calculations.
Leakage is calculated using area impacted, percentage of displaced activity, and carbon stock differentials based on the formula:

$$Leakage = Affected\ Area \times \%Activity\ Shift \times CO_2\ Stock$$

If the displacement location is unknown, average CO_2-stock values for natural forests in the host country are used.

3.9 Overview of Parameters and Sources

Parameter	Unit	Definition	Source type
Planted Area	ha (hectares)	The total area of mangroves planted each year as part of the project.	Project specific data: satellite imagery and landcover classification model
AGB Sequestration Rate	tC/ha/year	Annual rate of carbon accumulation in the above-ground biomass (AGB) of mangroves per hectare.	Default rates (Tier 1) are taken from the IPCC 2019 Refinement, Volume 4, Chapter 4 (Table 4.9 & 4.10), which classify rates by several factors such as domain, continent, and species. Climate and ecological classifications follow IPCC Chapter 4, Table 4.1 (FAO, 2001). For regional or site-specific data (Tier 2 and 3), values may be refined using peer-reviewed studies or field measurements.
BGB to AGB ratio	Ratio (unitless)	Proportion of carbon stores below-ground relative to above-ground biomass	Default BGB-to-AGB ratios (Tier 1) are provided in the IPCC 2019 Refinement Volume 4, Chapter 4 (Table 4.4), categorized by region and species. Site-specific or species-based ratios (Tier 2 and 3) are prioritized, leveraging data from peer-reviewed studies or field measurements.
C-to-CO_2 Conversion	Ratio (unitless)	Conversion factor to calculate equivalent CO_2 from stored carbon, using the molecular weight ratio.	IPCC 2006 Guidelines or standard conversion factor (44/12 = 3.67).
Affected Area	Hectares (ha)	The total area within the project site where activities may cause leakage	Project site assessment, remote sensing data such as GIS mapping, land-use data, or historical satellite imagery

% Activity Shift	Percentage (%)	The estimated percentage of an activity (e.g., firewood collection, agriculture) that will be displaced outside the project area	Surveys, interviews with landowners, historical deforestation and land-use change data.
CO_2 Stock	tCO_2/ha	The carbon stock per hectare in biomass (tree biomass in forests or shrubs) in the area where displacement occurs	National forest inventories, IPCC guidelines, peer-reviewed literature, or host-country datasets on carbon stocks

3.10 Monitoring Requirements

Parameter	How to Monitor	Frequency
Planted Area	Satellite imagery and landcover classification model.	Annually
AGB Sequestration Rate	Monitor default rates provided by IPCC (IPCC 2019 Refinement Table 4.9 & 4.10), verification through regional studies in peer-reviewed literature.	Annually
BGB to AGB ratio	Apply default values from the IPCC 2019 Refinement (Table 4.4), for consistency, and use site-specific measurements or species-based ratios (Tier 2 or 3) for greater accuracy when available	Annually
DOM Sequestration Rate	Project-specific or species-specific data from peer-reviewed sources will be used for more accurate and localized estimates if available.	Annually
SOC Sequestration Rate	Project-specific or species-specific data from peer-reviewed sources will be used for more accurate and localized estimates if available.	Annually
Project Emissions	Default assumption of zero emissions for low-impact activities (Tier 1); monitor and estimate emissions (fuel use, transport logs etc.) for higher-impact activities using IPCC guidelines for Tier 2/3	Annually
Leakage	Analyze nearby areas using satellite imagery and computer vision models; conduct field surveys to detect land-use changes	Annually

4. References

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