The Global Tree C-Sink
Guidelines for the certification of tree-based carbon sinks

The present guidelines are valid as of 15th March 2024. For companies already certified under the pilot Global Tree C-Sink (version 0.9), a transition period until 31th December 2024 is applicable.

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Content

Goal and Scope of the Guideline

The Global Tree C-Sink is a novel certification guideline for the reliable quantification and adequate valuation of climate services generated by living plant biomass in either new plantations or natural regeneration.

These guidelines define the criteria for the endorsement and application of state-of-the-art digital monitoring, reporting, and verification (dMRV) technologies to support high-resolution, data-driven carbon accounting. Through this, the Global Tree C-Sink standard provides certification of climate services from nature-based carbon dioxide removal (CDR) solutions, ensuring accuracy, security, and traceability that is on par with industrial negative emission technologies, such as PyCCS, BECCS, or DACCS:

Accuracy	• State-of-the-art dMRV applications provide precise calculations of the C-Sink using empirical data. • Regular measurements ensure capturing the dynamics of tree-based C-Sinks with high temporal resolution.
Security	• Independent third-party verification and certification for all projects. • On-site monitoring generates empirical data. • Annual aerial imagery covers all certified surface areas. • Encouraging biodiversity and local species bolsters the resilience of the projects. • Every certified C-Sink demonstrates proven additionality.
Traceability	• For each certified unit of CO_2e, the exact location of the C-Sink is identified. Depending on the monitoring method, this can be tracked down to an individual geo-referenced tree.

While some industrial negative emission technologies have advantages in terms of C-Sink persistence (with no expected carbon leakage for over 1000 years), biomass-based C-Sinks present a temporal dynamic. Thus, biomass-based C-Sinks cannot be used to offset CO_2 emissions. Instead, the Global Tree C-Sink is designed exclusively for time-dependent mitigation of the global warming effects induced by CO_2 emissions. The overarching Global C-Sink framework introduces innovative and flexible tools, enabling proper valuation of climate services, such as Global Cooling Services (GCS).

In summary, the key value propositions and novelties of Global Tree C-Sink are:

1) Accreditation and employment of digital monitoring, reporting, and verification (dMRV) schemes to generate accurate, secure, and traceable C-Sink certificates.
2) A scientifically accurate approach to computing, paired with economically sustainable methods for valuing dynamic, time-sensitive C-Sinks that offset the global warming impact of GHG emissions.

The Global Tree C-Sink serves as an operational framework, setting forth stringent eligibility and sustainability criteria. These criteria guarantee social, environmental, and economic safeguards for every project. Furthermore, mechanisms have been put in place to record and offset project emissions, referred to as "carbon expenditures ".

A pivotal component of the certification process involves evaluating the botanical diversity inherent in the C-Sink projects. Subsequently, every certified initiative is categorized into one of three distinct biodiversity levels.

Through lean administrative processes and a dMRV system, certification is made cost-effective for projects ranging from small to large scales. All projects are initiated, overseen, and continuously monitored by C-Sink Managers endorsed by Carbon Standards. C-Sink Managers are local organizations responsible for executing and upholding tree planting projects in line with the Global Tree C-Sink guidelines. They relay project data to the "Global C-Sink Registry" and undergo annual third-party audits (i.e., by the Certifier).

The geographical validity range of the present guideline is global.

Background:
The relevance of nature-based carbon dioxide removal (CDR)

A. The Importance of trees and forests

Trees and forests are essential components of the climate system. They influence global carbon fluxes, impact regional climate patterns, and are home to a significant portion of the world's biodiversity. Depending on the forest definition, the global forest cover ranges from 2.8 billion ha to 4.1 billion ha, which is more than 30% of the Earth's surface (Bastine et al., 2019; FAO, 2022). From 1990 to 2020, more than 0.4 billion ha of forest were lost. While the rates of deforestation and forest degradation have decreased relative to past decades, they are still high. More than 10 million ha of forest were lost annually from 2015-2020, which includes the nearly 50 million ha of primary forest lost over the last two decades (FAO, 2022). Currently, forests store more than 600 Gt carbon globally. However, unchecked deforestation and abiotic stresses from climate change may soon turn the global forest into a net CO2 source, with higher CO2 respiration than assimilation rates.

Forests play a multifaceted role in sustaining livelihoods, conserving biodiversity, and regulating local climates. They provide timber, non-timber forest products (NTFPs), and habitats, and are integral in regulating the water cycle. Continued deforestation in the tropics not only affects rainfall patterns but also has cascading effects on rainfed agriculture (FAO, 2022).

The world's biodiversity is in a critical state, amounting to a crisis that must be addressed alongside the climate crisis (IPBES, 2019). Forests are bastions of terrestrial biodiversity. They shelter 80% of amphibian species, 75% of bird species, and 68% of mammal species. This includes endangered flagship species like orangutans, gorillas, forest elephants, and jaguars. Additionally, forests are home to 60% of all vascular plants. About 20% of the world's forests are legally protected, however, this protection is often ineffective. To address these challenges, the Food and Agriculture Organisation of the United Nations (FAO) recommends a threefold strategy:

1. Halting deforestation and forest degradation.

   (This measure alone could prevent emissions of up to 3.6 Gt CO2 annually.)

2. Forest restoration, afforestation, and expansion of agroforestry.
3. Fostering the sustainable use of forests for green value chains. (This encompasses both bio-economy products and ecosystem services linked to the global carbon markets.)

B. The global potential for tree planting initiatives

The potential for afforestation[1] is vast. Under current climatic conditions, which include water availability, the Earth has the capacity to support 4.4 billion ha of forest. However, only 2.8 billion ha are currently forested. Of the 1.6 billion ha difference, 0.7 billion ha are allocated to other anthropogenic land uses, such as urban areas and agriculture, which may not be feasible for full conversion to forest. This leaves about 0.9 billion ha of land, theoretically available for afforestation (Bastine et al., 2019). When fully forested, these 900 million ha (roughly the size of the United States) could, in their climax state, sequester an astounding 205 Gt C (752 Gt CO2e). This amount is comparable to two-thirds of the anthropogenic CO2 emissions released since the beginning of the industrial revolution, or more than 90% of the 800 Gt CO2 removal necessary to remain within the 2°C global warming target outlined in the Paris Agreement (IPCC, 2018; Bastien et al., 2019, Smith et al. 2023).

The findings by Bastien et al. (2019) regarding global afforestation potential and C-Sink potentials ignited considerable scientific debate. Subsequent uncertainties were addressed in a later erratum, and the forest C-Sink potential was revised to a range of 133.2 to 276.2 Gt C (Bastien et al., 2020). Yet, the general consensus remains: globally scaled afforestation efforts have the potential to sequester up to 10 Gt CO2e annually (IPCC, 2019, also referenced by: WRI, 2023).

Beyond traditional afforestation, the integration of trees into urban and agricultural landscapes offers significant carbon sequestration potential. Incorporating more trees and vegetation within cityscapes has become an essential aspect of climate change adaptation, diminishing the urban heat-island effect and simultaneously acting as biodiversity corridors.

The scope for embedding trees within agricultural landscapes, through agroforestry systems and hedges, is also expansive. Agroforestry polycultures, which combine various crops and trees, can yield greater biomass per area than separate monocultures, applicable in both temperate and tropical ecosystems (Miah et al. 2018; Sesermann 2018). With increasing temperatures leading to enhanced wind speeds and consequent moisture loss from crops,

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[1] Afforestation involves planting trees with the goal of establishing a forest on land that hasn't been recently covered by trees. In contrast, reforestation pertains to the restoration of land that was recently forested (American University Washington DC, 2023). The time span used to distinguish between afforestation and reforestation—based on the period of non-forest cover—varies among definitions, typically ranging between 10-30 years. Generally, afforestation activities are considered as additions, whereas reforestation activities are seen as replenishments of recently depleted carbon stocks. The Global Tree C-Sink is fostering afforestation regardless of the time passed since deforestation, not delaying vital restoration initiatives.

agroforestry emerges as a pivotal adaptation strategy. Trees in such settings provide crucial shade, thereby safeguarding crops.

The burgeoning bio-economy, with its growing appetite for locally produced biomass, will likely stimulate the adoption of agroforestry elements and specialized biomass production systems. The IPCC postulates that, when managed sustainably, agroforestry systems can sequester approximately 1Gt CO2e annually on a global scale (IPCC, 2019). Additionally, agroforestry stands as a prominent strategy for climate change adaptation within the agricultural sector (Mbow et al., 2014).

C. Integrating biodiversity and conservation areas

“Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems” (CBD, 1992).

Climate change and biodiversity loss are deeply intertwined crises that reinforce each other and must be addressed concurrently. Often, strategies aimed at combating climate change have the added benefit of preserving biodiversity. The synergy between these objectives is most evident in nature-based carbon removal approaches, such as afforestation, landscape restoration, and climate-smart agriculture and forestry. These strategies not only sequester carbon but also promote diverse, resilient ecosystems. As efforts to counteract climate change intensify, it's imperative to choose solutions that provide comprehensive benefits for our planet.

While landscapes with minimal or no tree cover, such as deserts or cultural landscapes, can also host significant biodiversity, it's undeniable that degraded lands can benefit from restoration measures. When smart and varied selections of tree species and landscape features are made, afforestation or appropriate restoration can enhance biodiversity. This, in turn, boosts downstream ecosystem services, including carbon sequestration.

Prioritizing afforestation and restoration projects that emphasize both inter-specific and intra-specific (avoiding clones) botanical diversity not only enhances plant diversity but also paves the way for increased animal diversity due to the resulting improved and varied habitats. Moreover, the significance of integrating trees into human-made landscapes has gained recognition. For instance, the European Union has recently recognized the value of agroforestry. It's now not only seen as a permissible practice under the Common Agricultural

Policy (CAP) but also as an eco-scheme, highlighting the voluntary contribution to environmental public goods through pillar 1 payments (European Union, 2021).

Conservation areas, safeguarded from destruction and high-impact interventions such as harvesting, play a pivotal role in slowing down global biodiversity loss. These undisturbed conservation, core, or wilderness regions offer indispensable habitats, corridors, and sanctuaries for a myriad of endangered species.

The pioneering proposition to designate 30% of terrestrial and 30% of marine areas as protected zones emerged in 2019 from the article "A Global Deal for Nature: Guiding principles, milestones, and targets" by Dinerstein et al. This proposal subsequently gained traction and was ratified during the United Nations Biodiversity Conference in Montreal (COP15). Consequently, it crystallized into a global objective within the Kunming-Montreal Global Biodiversity Framework (CarbonBrief, 2022). This ambition of the Kunming-Montreal framework has garnered support from heavyweight entities such as the European Union and the G7 nations. In fact, the European Union has proactively embedded the "30 by 30" aspiration within their EU 2030 Biodiversity Strategy, an extension of the European Green Deal (European Union, 2020). Ambitiously, there are other initiatives, like the "Half Earth Project," which advocate for even loftier conservation benchmarks (Half Earth, 2023).

Tree planting projects exert a significant spatial influence on landscapes, with individual projects spanning from several hundred to thousands of hectares. Therefore, integrating conservation areas systematically into afforestation initiatives offers a promising avenue for enlarging these crucial habitats. A global standard for such a mechanism is both urgent and indispensable.

D. The ambition and reality of tree planting initiatives

In recent years, land restoration and afforestation have received increasing political attention, culminating in numerous large-scale restoration initiatives and tree-planting pledges. The Bonn Challenge, launched in 2017 by the German Government in conjunction with the International Union for Conservation of Nature (IUCN), encapsulated pledges to restore 150 million ha of land by 2020 and further extend that to 350 million ha by 2030 (Bonn Challenge, 2023). Similarly, the African Forest Landscape Restoration Initiative aims to restore 100 million ha of land in Africa by 2030 (AFR100, 2030). Aligning with these endeavors, as a facet of the European Green Deal, the European Union has committed to planting 3 billion trees. This initiative bolsters its biodiversity strategy with the overarching goal of achieving climate neutrality by 2050 (European Union, 2020, 2023).

While the ambitions set are lofty, they are not without challenges. Stakeholder and land-use conflicts, hurdles in monitoring such as tracking tree survival rates, and a significant financial shortfall impede the realization of these goals. As a case in point, African nations have collectively pledged the restoration of 129 million hectares of land, inclusive of forests, with a target set for 2030. Yet, ground realities paint a different picture, with a net loss in forest cover reported for almost every sub-Saharan African nation. These losses range from -2% to -10% between the years 2000 and 2022 (Global Forest Watch, 2023). The State of the World’s Forests Assessment 2022 aptly summarizes the situation, stating, “Forests and trees provide vital goods and ecosystem services, yet their economic value remains underestimated in economic systems” (FAO, 2022).

Connecting afforestation projects with the global carbon market offers an opportunity to add economic value and equip projects with sophisticated dMRV technologies. However, historically, the challenge has been how to appropriately account for and value carbon sinks based on trees, given the non-permanent nature of carbon stored in biomass. Any CO_2 that is removed from the atmosphere provides a cooling effect for as long as it remains stored outside the atmosphere. The cooling effect depends on the actual time when a CO_2 removal occurred and diminishes over time (Jeltsch-Thömmes and Joos, 2019; Zickfeld et al., 2021). Importantly, providing a cooling effect doesn't equate to offsetting previous CO_2 emissions. To fully compensate for the effect of a fossil CO_2 emission, a C-Sink of equal size must be created for as long as the global warming effect of a CO_2 emission persists which is millions of years. This can never reliably be achieved by solely biomass-based C sinks. For more on this, refer to “The Global C-Sink guidelines” on feedback transmission and reflux.

While biomass-based C-Sinks cannot produce permanent carbon sequestration, they do offer an immediate solution for carbon dioxide removal (CDR). This swift action is crucial for slowing down climate change and averting the activation of potential tipping points in our climate systems (Rising et al., 2021; Armstrong-McKay et al., 2022). Moreover, afforestation may produce carbonaceous feedstock to produce permanent carbon sinks such as PyCCS, BECCS, and bio-based materials. Afforestation can be scaled up immediately, offering additional advantages beyond carbon sequestration.

The Global Tree C-Sink guidelines provide a comprehensive framework for certifying the carbon removal, biodiversity, and additionality of sustainable tree planting projects. The guidelines detail how dMRV can be employed to ensure accurate and precise carbon accounting and how to assign value to climate services provided by these temporal C-Sinks.

Box 0.1 What is the difference between a CO_2 offset (synonymous with C-credit) and a Global Cooling Services (i.e., global warming compensation)?

"Carbon Offset"	"Global Cooling Service"
Product (one time purchase).	**Service** (purchased for a duration of service).
Complete compensation of an equivalent emission.	**Compensation of an equivalent global warming effect** of an emission, over a defined time horizon.
Unit: **t CO_2e** (t CO_2 equivalent)	Unit: **t aCO2e** (ton annually stored CO_2 equivalent)
Value proposition: **120-150 € per t CO_2e** (>1000 years persistence)	Value proposition: **3€ per t aCO_2** (1/50 value of persistent C-Sink; can be sold annually)
Scope: **Only C-Sinks of proven >1000 years persistence**	Scope: Flexible and inclusive mechanism for assessment and valuation of **any C-Sink** in function of the C-Sink lifetime.

1. Eligible Project Types and Spatial Organization

1.1 Eligible Project Types

This certification guideline (version 1.0 January 2024) applies to any project where **additional** trees are established as part of the project activity within a registered management unit that meets the land eligibility criteria outlined in chapter 5.

The project activity can involve active tree planting or support of natural and managed-natural restoration[2], facilitating the afforestation of expansive land areas, including those with limited accessibility.

Improved management of existing forests and forest protection play equally a crucial role in carbon sequestration and emission avoidance but cannot be certified under the current standard due to additionality requirements.

The Global Tree C-Sink guideline distinguishes between six possible project types, defined in Table 1 below.

Table 1: Eligible Project Types

Project Type	Characterisation
Afforestation	Actively replanting of forest, with ≥ 2 species, on land that is currently not covered by forest. (restrictions in reproducing carbon stocks of preceding biomass cover apply as per chapter 5.1)
Plantations	Active replanting of forest-like vegetation, with < 2 species, on land that is currently not covered by forest and where the plantation does not lead to an establishment of a forest but a form of tree cropping with no botanical diversity. (further restrictions as per chapter 5.1).
Agroforestry	Active planting of trees integrated in agricultural landscapes, e.g., alleys, windbreaks, hedges, riparian buffers, forest gardens, silvo-pastoral systems, etc.

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[2] Active tree planting is not always feasible, nor technical possible. However, the natural- or managed natural restoration of degraded land bears large potential. A project activity for the latter scenario creates the enabling conditions to facilitate natural restoration, e.g., by prevention of fire, management of grazing, catalysation of seed germination, provision of alternative income to land users etc. Natural restoration relies on the soil's natural seedbank, while managed-natural restoration may modify the seedbank and manage the regrowth.

Urban trees	Active planting of trees outside of a future forest biome. Trees are integrated into urban landscapes e.g., roadside trees, parks, micro-forests, rooftop trees, etc
Natural Restoration	Actively creating the enabling conditions for natural- or managed-natural restoration of forest on land that is currently not covered by forest. (further restrictions as per chapter 5.1).
Conversion of monoculture forest or perennial agricultural plantations	The removal of forest-like vegetation, presenting an artificial monoculture system[3] and consecutive establishment of a system with improved botanical diversity e.g., polyculture or natural forest.

1.2 Spatial Organization of Projects:

Project Area

A project area refers to the designated region where a C-Sink Manager initiates and oversees tree-planting endeavors. It functions as a reference point for both the C-Sink Manager and certifier, allowing for the strategic clustering of management units as needed. For instance, this can be based on differing local legislation across states or provinces, or on projects coordinated by distinct local organizations. The term "Project area" is not confined by any specific spatial definition or boundary.

Management unit

Every tree planting project must be organized into distinct management units. A management unit is a spatially contiguous, georeferenced (mapped) land area, spanning up to a maximum of 50 ha, designated for tree planting or regeneration. A cluster of closely associated, however not spatially contiguous, smallholder plots can likewise be registered as a management unit if subject to the same management plan and located all together in a radius of not more than 5 km. Each management unit must possess a unique ID and be associated with a specific project area. While the initial registration of a management unit may cover less than 50 ha, it can be updated and expanded at a later time. There's no restriction on the overall spatial extent of a tree planting project since project areas (as defined above) can consist of multiple management units, whether adjacent or dispersed.

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[3] A C-Cink Manager must outline a strategy for maximal C preservation in the terrestrial system and erosion control during system conversion.

C-Sink Unit

A C-Sink Unit is defined as a contiguous land area spanning up to a maximum of 10 ha, which forms part of a larger management unit. For instance, a 50 ha management unit would be subdivided into at least five separate 10 ha C-Sink units. Every C-Sink unit must be georeferenced (mapped), assigned a unique ID, and linked to its respective management unit. Serving as the primary unit for monitoring, reporting, and verification, the C-Sink unit will be certified and listed in the Global C-Sink Registry. Consequently, any tree assessed for its C-Sink capacity must be associated with the specific C-Sink unit ID

2. Carbon Accounting

The Global Tree C-Sink standard doesn't prescribe specific tree growth monitoring technology. Instead, it sets criteria for the data's accuracy and precision. This approach encourages technological innovation and permits solutions tailored to individual projects and contexts. Carbon accounting methods can encompass various measurement strategies, including single-tree tracking, digital-twin modelling, grid-cell based monitoring of CO_2 fluxes via satellite data, correlating C stock to canopy elevation, or utilizing Light Detection and Ranging (LIDAR) techniques. Multiple technological solutions can be combined and adapted by different organizations or within distinct local contexts.

Before any growth monitoring technologies and protocols can be used for carbon accounting under the Global Tree C-Sink standard, they must first be verified and endorsed by Carbon Standards.

2.1 Basic Requirements for Carbon Accounting

Carbon accounting methods must adhere to the following requirements:

- **Context-Specific Accuracy**: Whether applied to an individual tree, a hectare of land, or a larger grid-cell, within the defined validity range of the method, the carbon accounting method must be validated against ground data and yield results with an accuracy level of ±10%.

- **Digitalization**: To enhance efficiency and minimize human error, processes should be as automated and digitized as feasible. Use of digital monitoring, reporting, and verification (dMRV) applications is recommended.

- **Spatial Coverage**: A dMRV method, appropriate to the project type and project scale must be capable of monitoring 100% of the project area. Certifications according to the Global Tree C-Sink are 100% based on empirical data. Data extrapolation from discrete sampling plots is not permitted.

- **Temporal Resolution**: The method must provide the technical capability and economic feasibility to monitor the entire project area at a temporal resolution of at least 5 years. This could mean measuring the entire area every five years or evaluating, e.g., 20% of the area each year.

A C-Sink Manager or an external service provider may seek approval for their monitoring technology and protocol from Carbon Standards. Only results from Carbon Standards - approved technologies will be accepted, and approval is renewed annually.

While the precise functioning and methodology of a specific technology remains the intellectual property of the C-Sink Manager or the external service provider, a generic description of each approved measurement approach, together with its essential requirements for quality and performance, will be included in the frequently updated Annex I of these guidelines. It will also be featured on the Global C-Sink website (www.global-C-Sink.com).

For submitting new C-accounting methods, see chapter 10, "*Certification*".

Table 2: Accredited dMRV technologies for carbon accounting (as of 01/2024)

Measurement approach	Accredited technology
Single Tree Tracking	TREEO App

2.2 Expected C-Sink Curves

C-Sinks can only be certified after the removal of carbon dioxide has physically taken place (i.e., ex-post). Once certified, these C-Sinks are recorded in the Global C-Sink Registry and can be traded by Carbon Standards -endorsed companies as global cooling services.

For tree-based C-Sink projects, significant upfront investments are often necessary. To address this, the Global Tree C-Sink also offers the option to certify expected C-Sink curves. An expected C-Sink curve outlines the anticipated quantity of carbon to be removed and stored in the C-Sink over time. A certified expected C-Sink curve is not equivalent to an actual C-Sink, is not registered as C-Sink, and cannot be traded for emission compensation. Expected C-Sink curves may, however, help to conclude pre-purchase agreements, ensuring the necessary upfront investment.

An expected C-Sink curve is generated by the C-Sink Manager and must be based on average growth data in the region considering forest type, tree species composition, climate, soil, planting density, management, and regional fire- and infestation risks for the respective forest type. A generic protocol on the establishment of expected growth curves will be established under version 2 of these guidelines.

The expected C-Sink curve, whether calculated for a management unit or C-Sink unit, must be submitted to Carbon Standards. This submission should include a step-by-step explanation of the calculation, pertinent references, and any original data where applicable (e.g., a growth curve from literature, a model, or empirical data from a reference management unit). As projects progress, the dMRV applications will gather data, which will then be utilized to refine the growth prediction models. The expected C-Sink curve should undergo quantitative updates at least every 5 years, based on the empirical data collected.

The Carbon Standards -approved certifier reviews the data, calculation, risk assessment, and expected C-Sink curve for plausibility. Upon approval, a security margin of at least 20% is added to the expected C-Sink curve. If an expected C-Sink curve is rejected by the certifier, the C-Sink Manager has the option to revise and resubmit.

It should be noted that these expected C-Sink curves serve merely as guidance for C-Sink Managers and their partners; there are no obligations or liabilities toward the certifier if the expected C-Sink curve is not achieved.

2.3 Soil Organic Carbon

If all the principles of sustainable management and land eligibility, as detailed in chapters 4 and 5, are adhered to, deterioration of soil organic carbon (SOC) is unlikely. Consequently, a quantitative assessment of SOC development is not mandated.

At present, the Global Tree C-Sink guidelines do not encompass the assessment or certification of SOC. In the future, dynamic SOC-based C-Sinks might be certifiable under a distinct methodology endorsed by Carbon Standards or integrated into accredited dMRV technologies for carbon accounting in tree-centric systems.

For project areas certified under the Global Tree C-Sink, aiming to secure certification from external SOC schemes, a detailed authorization request must be submitted to CSI. It's worth noting that, currently, a universally accepted scientific consensus on appropriate methods for quantifying SOC for C-Sink certification remains elusive.

2.4 Storage and Transfer of Primary C-Sink Data

Storage of primary C-Sink data and its transfer through Application Programming Interfaces (API) to the Global C-Sink Registry:

The designated dMRV must be enabled to transmit all pertinent data first to the project's own primary database (for example, using individual tree data in the single tree tracking approach). This project-specific database must feature an API connection to the Global C-Sink Registry. This ensures that the quantified C-Sink, aggregated by the pre-defined C-Sink units within the project, is seamlessly transferred. Additionally, relevant supplementary data, such as C-Sink type, geolocation, and timestamp of measurement, must accompany this data transfer. Based on this API, the Global C-Sink Registry will automatically receive basic project information for each registered C-Sink. The C-Sink Manager is mandated to retain the comprehensive, **non-aggregated** dataset for a minimum of 10 years. Carbon Standards or the certifier may request access to the complete dataset or specific sections of it as deemed necessary. Once the aforementioned data is transmitted to the Global C-Sink Registry, the certifier will validate it. Only after this validation step will the respective C-Sinks and, thus, its global cooling service be officially registered.

3. Biodiversity Ranking

The diversity and integrity of an ecosystem correlates with its resilience, e.g. resistance to drought or pests, directly reducing the risk of C depletion or complete loss of the C-Sink due to stressors. To acknowledge the importance of tackling climate change and biodiversity loss at once, the present guidelines require benchmark levels of botanical biodiversity *("B" indicators)* and conservation areas *("C" Indicators)* nested into projects applying for certification.

To further promote higher biodiversity and nature conservation standards, the Global Tree C-Sink guidelines establish a ranking system, classifying projects into three biodiversity & nature conservation levels, see Table 3.

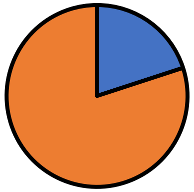
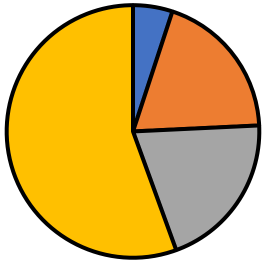
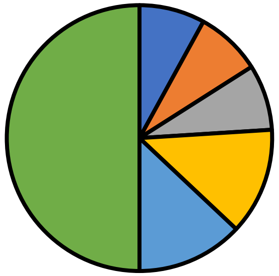
All projects must meet the basic principles to promote botanical biodiversity and nature conservation as per Level I to be eligible for certification.

Additionally, voluntary biodiversity and conservation measures will lead to a higher ranking, awarded as Level II (two butterflies) and Level III (three butterflies), respectively. The biodiversity level will be awarded and indicated with the C-Sink certificate and becomes visible in the Global C-Sink Registry, favouring premium pricing.

The biodiversity ranking does not apply to urban projects.

All conditions for level I are also requirements for level II. All conditions for level II are also requirements for level III.

Table 3: Principles of biodiversity and nature conservation

Level I		Level II *Indicators additional to level I*		Level III *Indicators additional to level I and II*	
B01	The management unit contains ≥ 2 tree species. The dominating tree species must cover less than 80% of the management unit or present less than 80% of the total number of trees planted in the management unit. The project presents a minimal species composition as shown below:  It is permitted to arrange the 2 species in segregated blocks.	B05	The management unit contains ≥ 4 tree species. The dominating tree species must cover less than 55% of the management unit or present less than 55% of the total number of trees planted in the management unit. Jointly, the **two** dominating species must represent less than 75%. To be recognized, each associate tree species must cover at least 3% of the management unit or present 3% of the total number of trees in the management unit. The project presents a minimal species composition as shown below:  It is not permitted to arrange the 4 species exclusively in segregated blocks. At least 30% of the management unit must constitute a mixed forest stand.	B08	The management unit contains ≥ 6 tree species. The dominating tree species must cover less than 50% of the management unit or present less than 50% of the total number of trees planted in the management unit. Jointly, the **three** dominating species must comprise less than 75%. To be recognized, each associate tree species must cover at least 3% of the management unit or present 3% of the total number of trees in the management unit. The project presents a minimal species composition as shown below:  It is not permitted to arrange the 6 species exclusively in segregated blocks. At least 60%

					of the management unit must constitute a mixed forest stand
B02	All planted tree species are considered as non-invasive by the designated national authorities in the country of project location. (Not applicable for natural regeneration)	B06	No synthetic pesticides are used in the management unit. (Herbicides, insecticides, fungicides, aborticides etc.)[4]. Organic pesticides are permitted. B05 is not applicable for agroforestry projects[5]	B09	≥ 60% of the planted trees are native or naturalized to the region and regarded as climate resilient in the project area (referenced, scientific recommendation)
B03	All chemical inputs used in the management unit are legal in the country of project location and are not listed as "Extremely hazardous" or "Highly hazardous" as per Table 1 and Table 2 of the "WHO Recommended Classification of Pesticides by Hazard" (WHO, 2019). Users must be familiar with the manufacturer's application instructions.	B07	In ≥10% of a management unit, trees are planted scattered, or in patterns other than straight lines, to improve protection from predators including humans. B06 is not applicable for agroforestry projects.	B10	≥5 % of the trees planted and maintained in a management unit represent endangered or near to threatened species according to the IUCN classification (red list). Eligible status: NT=Near Threatened, VU=Vulnerable, EN=Endangered, CR=Critically Endangered, EW=Extinct in the wild.
B04	The dominating tree species is regarded as native or naturalized in the country of project location.			B11	In ≥30% of the project area, trees are planted scattered, or in patterns other than straight lines, to improve protection from predators including humans. B11 is not applicable for agroforestry projects.

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[4] Chemical pesticides may only be used in rare instances, such as when the entire tree planting project is at risk. If they are used, the certification body must be notified immediately. However, these pesticides should never be part of the standard management plan or used to protect Non-Timber Forest Products (NTFPs).

[5] This exception is meant to not exclude agroforestry systems from becoming parts of conventional agricultural systems.

C01	Management units must contain a spatially coherent (clustered and non-fragmented) forested area which is excluded from any tree logging for 30 years. The area contains native forest-like vegetation or must be afforested with ≥tree species presenting a density that can be defined as forest. The harvest of NTFPs is still encouraged. The protected area comprises at least 10% of the management unit and is referred to as the conservation area of the management unit. Actively afforested conservation areas can be part of the carbon monitoring. C01 is not required for the certification of agroforestry projects and for management units < 3ha.	C02	The logging-protected area (defined in C01) comprises at least 20% of the management unit and is referred to as the conservation area of the management unit. C02 is not required for the certification of agroforestry projects and for management units < 3ha.	B12	No chemical synthetic commercial fertilisers are used in the management unit. Organic fertilizers such as manure, compost, or biochar-based fertilizers are permitted. B12 is not applicable for agroforestry projects.
		C03	If partial clear cuts occur, the non-logged areas (between the clear cuts) must be spatially coherent (connected) with each other or with the conservation area as per C02 This is to provide larger core areas and longer connective corridors. C03 is not applicable for agroforestry projects.	C05	The logging-protected area (defined in C01) comprises at least 30% of the project area and is referred to as the conservation area of the management unit. C05 is not required for the certification of agroforestry projects and for management units < 3ha.
		C04	If partial clear cuts occur, habitat trees must be maintained at > 5 trees/ha in the logged areas.	C06	Electrical chainsaws and tools are promoted and used to lessen emissions, noise pollution, and animal stress. C06 is also fulfilled if no power tools are used for tree management in the management unit.

Plantations: The project type "Plantations," monoculture afforestation projects aiming for maximized biomass production, is excluded from the ranking framework as outlined in Chapter 2.

From a local, ecological point of view such systems deprived of botanical diversity are not desired. However, plantation systems are highly efficient in delivering biomass, and with it, biomass-derived carbon is urgently needed in the transition of the global economy away from fossil-derived carbon, an ecological benefit that comes into play not at the local but at the global level. (See also: "Planetary Carbon Recycling", Schmidt and Hagemann (2024))

Recognizing this factor, monoculture plantations optimized for biomass production may be certified under the global Tree C-Sink guidelines if the plantation is not larger than 10 ha and is surrounded by a conservation area (defined as per C01, Table 3) of at least equivalent size to the plantation area (e.g. a 20 ha MU comprised of 10 ha monoculture plantation and 10 ha conservation area) and all principles outlined in chapter 4 "Sustainable Forest Management" and chapter 5 "Land eligibility" are observed during establishment and management, including harvest, of the plantation. The conservation area must not consist of scattered forest sites but must be one unique site where all parts are clearly connected with each other. Such continuous habitats must allow for the free movement of species across different parts of the conservation area.

Urban Trees: The project type "Urban Trees" may refer to solitary roadside trees, roof-top greenery, or micro forests. Typically, "Urban Trees", projects are excluded from the ranking framework as outlined in chapter 2. On a case-by-case basis, micro forest projects may be compatible with the ranking framework.

4. Sustainable Forest Management

To prevent environmental degradation caused by unsustainable practices and to promote a high level of climate and ecosystem services, the Global Tree C-Sink has established the following set of specific rules for tree planting and restoration projects. All principles laid out in the following ten sections must be thoroughly documented in the management plan for each management unit.

1. **Land preparation**
   - During the land preparation phase for tree planting, the soil must remain undisturbed. Draining, inverse tilling, burning, or slash-and-burn techniques are strictly prohibited.
   - The creation of planting furrows through ripping, as well as the digging or drilling of planting pits, is permissible.
   - If biomass, such as the scrub layer, is removed to facilitate planting or promote healthy tree establishment, it must not be burned on-site. Instead, it can be repurposed as mulch or pyrolyzed to produce biochar.
   - Exceptions may be considered by the Carbon Standards for moderate tillage operations, specifically if the intention is to encourage germination from a natural seed bank in restoration projects.

2. **Retaining remnant trees**
   - If single trees or scattered groups of trees with a DBH >10cm in temperate and arid zones and a DBH >25cm in humid tropical and sub-tropical zones are present in the planting area of the management unit, the trees must be preserved. These trees act as service and habitat trees, providing shade for emerging trees, guarding the ground against direct sunlight, and functioning as wildlife conduits. An exception applies if a tree is considered invasive locally, warranting its removal.
   - Remnant trees that remain in the management unit become integral to the project and can be included in the dMRV scheme. If so, the monitoring tools must be updated accordingly (i.e., if a single tree tracking approach is employed, the species of the remnant tree must be known, and the dMRV application must encompass the respective allometric equation).
   - Carbon assimilated by remnant trees is considered part of the baseline scenario and shall not be included in the dMRV based carbon accounting.

3. **Mineral fertilization**
   - If fertilization is deemed necessary, preference should be given to organic fertilizers, such as manure, compost, or biochar-based fertilizers. This promotes the recycling of local resources and contributes to the accumulation of soil organic carbon.
   - The use of mineral fertilizers is permitted only during the initial five years after planting or after replanting following a harvest. During this period, mineral nitrogen fertilizer application must not exceed a rate of 100 kg N ha^{-1} year^{-1} and mineral phosphorus fertilizer should not surpass 100 kg P_2O_5 ha^{-1} year$^{-1.}$ These stipulations

are set to limit nitrogen-driven GHG emissions and prevent eutrophication of natural ecosystems.
- Emissions caused by the production and application of fertilizers are factored into the project's emission balance, as detailed in Chapter 6, "Carbon Expenditures".

4. Permanent ground cover
   - To safeguard against degradation of soil organic carbon and soil erosion, a permanent ground cover must be established and maintained, preventing the exposure of barren soil. A "permanent ground cover" is characterized by more than 75% of the soil surface being covered by living or dead biomass throughout the year. This coverage can be the result of naturally occurring litter layers or ground vegetation. When required, it can be deliberately established by under-sowing cover crops such as perennial grass, crawlers or nitrogen-fixing plants.
   - In natural forest systems that already have a leaf litter ground cover, no additional cover crop should be sown as this could impede natural regeneration.
   - In agroforestry systems, the crop rotation should incorporate a cover crop to prevent soil exposure.

5. Irrigation
   - Seedlings can be irrigated for up to five years after planting to increase survival rates. After this period, the use of ground or river water for irrigation is not permitted due to the potential disruption of regional water cycles and the risk of triggering conflicts.
   - Irrigation using water sourced from fog-harvesting or water desalination powered by renewable energies remains unrestricted.

6. Climate positive management:
   - The annual global cooling effect of a forest, in each respective year since project initiation, must consistently exceed the annual global warming effect that may be caused by the use or inappropriate management of the forest biomass. As a forest matures, the annual global cooling impact from carbon removals in previous years starts to diminish. If forest biomass decomposes or is burned, the resultant annual global warming effect will be greater than the cooling effect generated by the earlier removal of the atmospheric carbon. This discrepancy arises due to the time lag between carbon removal and its eventual emission, as well as the reflexive return (reflux) of CO_2 following its initial removal. For an in-depth understanding, consult the Global C-Sink Standard and refer to Figure 1.
   - To ensure that the forest's annual global cooling effect isn't overshadowed by global warming, more biomass-bound C must be preserved in the terrestrial system, than is decomposed, or burned. Certified C-Sinks produced from the harvested biomass such as wood construction or biochar is considered as carbon preservation. This balance is ensured by adhering to the following principle 7 and the promotion of "Downstream C-Sinks" (see chapter 13).
   - The Global C-Sink Registry calculates and verifies both the annual global warming and global cooling effects. Their calculation tool is openly accessible and can be used by C-Sink Managers without any charges.

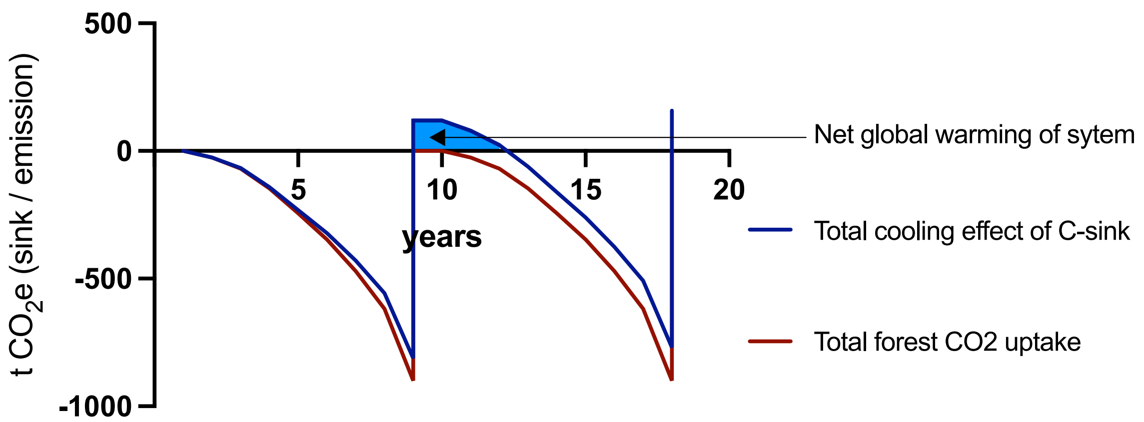

Figure 1: Example of a tree plantation that removes a total of 900 t CO_2 in the first nine years, yielding an annual global cooling effect of 770 t CO_2e. At the end of the ninth year, the entire forest is clear-cut, and the wood is burnt for energy generation, releasing 900 t of CO_2, which results in an annual net warming of the system of (900 tCO2e – 770 tCO2e=) 130 t CO2e during the 10th year of the system. The regrowing forest only achieves a net annual global cooling effect again by the 14th year.

7. Harvest practice

- Clear-cutting an entire C-Sink or management unit is prohibited. Such practices result in a net loss of carbon, impacting not only the trees but also the carbon stored in the soil. Furthermore, the devastation to habitats crucial for biodiversity preservation is substantial.
- At all times, a minimum of 40% of the carbon assimilated by the biomass within a C-Sink Unit must be retained. For illustration, if the highest carbon stock ever recorded for a C-Sink Unit amounts to 100 t CO_2e, then at least 40 t CO_2e must always be retained in living tree biomass. This allows for a maximum wood harvest that is equivalent to 60 t CO_2e. Should the carbon stock in the future rise to a new peak of 200 t CO_2e, the reference value adjusts. Now, a minimum of 80 t CO_2e must be preserved, permitting the extraction of wood representing up to 120 t CO_2e.
- For verification purposes, the C-Sink Manager is required to document the quantity of carbon removed during the harvest. This can be achieved through the single tree tracking method as outlined in Annex I or by monitoring the carbon retained post-harvest.
- If a tree undergoes pruning or thinning, no documentation is necessary. The biomass involved is minimal when compared to the remaining trunk, crown wood, and belowground biomass. Moreover, pruning can enhance the overall growth conditions for the tree or a designated management unit while the pruned branches undergo short to mid-term regrowth.

8. Replanting after harvest
    - Areas within the management unit where tree harvesting has occurred must be promptly reforested.
    - Soil in the harvested areas should not remain exposed to direct sunlight and rain without a vegetative cover for a period exceeding three months post-harvest.
    - The density of trees in replanted areas must be equivalent to or greater than the density prior to the harvest, ergo, as indicated in the planting plan.
    - The chosen species for replanting should align with the broader planting strategy of the management unit.

9. Risk-assessment and risk-mitigation
    - Every project must provide an assessment of relevant internal- and external risks to the project, along with risk-mitigation strategies adequate to the local project context.
    - Risk-assessment and -mitigation strategies need to be presented in the project development documents (PDD) see chapter 10.1. The implementation of the pledged risk mitigation measures will be verified during the regular on-site audits.
    - The risk-assessment and -mitigation strategies must cover at least a) risk of high seedling mortality, b) risk of pests, and c) risk of fire.

10. Internal Control System (ICS)

- The Internal Control System (ICS) ensures compliance with sustainable management principles, including the rigorous quality of carbon accounting outlined in Chapter 2. The ICS undergoes continuous verification and adjustments as needed.
- Designed by the C-Sink Manager, the ICS operates as a project-specific control mechanism. Internal inspectors, appointed and trained by the C-Sink Manager, carry out its implementation. External auditors conduct on-site inspections to assess the ICS's structure, tasks, and effectiveness.
- The ICS mandates frequent on-site evaluations at each Management Unit (MU) to ensure adherence to sustainable management principles, the professional and reliable function of the dMRV system, and the verification of collected data—either in its entirety or through stratified random sampling.
- It also provides for structured reporting on potential non-conformities, corrective measures for these issues, and a list of sanctions for the failure to implement successful corrective actions.

5. Land Eligibility

While trees can thrive in a vast range of environments, not all lands are apt for tree-planting endeavors. It's crucial that forestation does not compromise larger carbon reserves or areas of significant biodiversity.

For instance, practices like draining wetlands, managing organic soils, converting permanent grasslands, or encroaching on conservation areas to establish secondary forests may result in a net decline in carbon sequestration. Such actions can also risk diminishing biodiversity. Consequently, the Global Tree C-Sink guidelines have outlined stringent land eligibility criteria. Projects must satisfy these benchmarks in their chosen locations to gain certification.

5.1 Baseline Land Use

The objective of the Global Tree C-Sink certification standard is to increase terrestrial carbon stocks and global CO_2 removal significantly. The preservation of existing forests and the creation of new robust forest biomes are both vital for reaching this goal. Preserving natural forests is paramount. However, it's crucial to recognize that although prioritizing the conservation of these areas is important, neglecting reforestation can have severe consequences. When land is deforested and left idle, it undergoes erosion, loses soil organic carbon, and experiences a decline in biodiversity. Recovering from these effects can take decades. Therefore, if land originally covered by forest is cleared for any reason, prompt action for reforestation is essential to prevent further soil degradation. The speed of afforestation is directly linked to how quickly the land can resume its role in effectively absorbing CO_2 from the atmosphere. While most will concur with these general principles, managing the global forest for its climate-mitigating services involves navigating more complex interests and conventions.

Under existing regulations, only the afforestation of non-productive land can be certified for carbon removal and subsequently create marketable assets. In contrast, preserving existing natural forests does not qualify for marketable carbon removal credits because forest preservation (avoided emissions) is not viewed as an activity that generates additional C-sinks compared to scenarios without human intervention.

Existing forests are viewed as natural assets. The carbon they extract from the atmosphere through biomass is seen as part of the inherent carbon cycle, and this is already accounted for in climate models. The annual global warming effect of a CO_2 emission decreases each year thanks to its continuous uptake by forests and other biomass growth. If the carbon uptake of natural (already existing) forests were counted as a negative emission to offset the global warming effects of fossil carbon emissions, it would result in a form of double counting, as this uptake is already accounted for in the natural carbon cycle (c.f., impulse response function). Consequently, climate policies have determined that only carbon removals that are additional to what occurs in natural systems can be considered as C-sinks eligible to compensate for anthropogenic CO_2 emissions. Carbon removals, to be considered in offset calculations, must demonstrate "additionality" beyond the capabilities of existing natural C-sinks. Afforesting barren or non-forested land is commonly recognized as "additional" because such land inherently lacks CO_2 removal activity.

However, this criterion introduces substantial environmental and economic challenges, particularly when envisioning global climate services. To prevent natural forests from being cut down to prepare land for certifiable afforestation, many forest standards have mandated that selected land for afforestation must not have contained any forest cover for a duration of 10-15 years. This 10 to 15-year benchmark was instituted to differentiate between forest activities that can demonstrate additionality and hence claim carbon credits and those that are inherent assets to be conserved / restored without eligibility for such credits. This demarcation between natural and additional is a pure convention.

Much of what is termed "barren land" was once forested. So, when does a logged tract of land cease to be recognized as a former forest? Should it be five years, ten years, or perhaps fifty years? From a physical and natural history perspective, a convincing argument can be made that any region where trees can thrive without the need for irrigation was likely home to a natural forest in the past. Such a forest would re-emerge, even in the absence of human intervention, given the soil did not degrade too much due to anthropogenic stressors (i.e., deforestation, erosion, mining, overgrazing). By this definition, afforestation projects could only claim "additionality" when the soil became too degraded for natural forest establishment. It could even be argued that soil degradation must have occurred more than 10 years ago as shorter delays may deliver a pretext to degrade soils for the sake of additionality of climate projects.
Laws and regulations should be logical, easily understood, and free from disproportionate side effects. **The imposed 10 to 15-year waiting period may indeed deter illegal logging. However, it concurrently postpones actions that could restore the bio-productivity of logged areas. This delay exacerbates land degradation, which intensifies rapidly when land remains barren - a condition ironically mandated to establish additionality.**

To navigate this challenge, the Global Tree C-Sink strategy sidesteps the usual delay regulation associated with the land use baseline. Rather than promoting a practice where deforested lands are left unused, the Global Tree C-Sink champions prompt afforestation. This swift action aims to recapture the carbon previously lost from the forested land, benefitting both the climate and the ecosystem. **However, to be eligible for claiming additional C-sinks from land that was recently covered by forest, the carbon stock of the afforested land must attain at least 30% of the average carbon stock of forested land in that specific region.** The regional benchmarks are delineated in Annex 3.A1 of the IPCC (2003) (c.f., Annex 2). While 30% might appear to be a modest benchmark, it represents the anticipated carbon regrowth within a span of 10 to 15 years following afforestation. Consequently, C-Sink Manager won't see compensation for the carbon sink until after this 10-year window. However, this approach sequesters significantly more carbon than policies that merely let deforested lands lie fallow.

The following rules apply to the land baseline for afforestation projects:

1. Land currently not covered by forest (see forest definition), can be selected for afforestation, regardless of its canopy history; no waiting period is required.
2. Comprehensive documentation of the land-use history spanning the last 10 years before project start must be submitted for each Management Unit. This includes **a) a written description of land use history, b) satellite images[6], and c) global forest watch excerpts[7].** The year when the first land preparation activities took place in the MU, is defined as the starting year of the Tree C-Sink project.
3. If the land was occupied by primary or secondary forests (see forest definition) within the previous 10 years, before project start, the new forest must first capture and store at least 30% of the carbon formerly stored in the previous forest. Average carbon stock figures for forests across various regions are referenced from Annex 3.A1 of the IPCC report (IPCC, 2003; see also Annex 2 of the present guidelines). **Only after reaching this threshold can carbon sequestration beyond the reestablished carbon stock be claimed as additional C-Sinks.** If the data from the prior harvest noticeably differ from the IPCC's average metrics, an application to adjust the benchmark values can be made to Carbon Standards.
4. If the land was occupied by primary or secondary forests within the previous 10 years, before project start, the reforested area must achieve a biodiversity rating of at least Level II.
5. If the land in question did not host primary or secondary forests in the decade preceding the start of the Tree C-Sink project, it is exempt from carbon penalties and biodiversity mandates beyond Level I. Vegetation that falls short of the criteria defined for forests—specifically, an area of at least 0.5 hectares, trees reaching a minimum height of 5 meters,

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[6] One year before project start and ten years before project start.

[7] Spanning the ten years before project start

and a canopy cover of 30% or more—is classified as bushland rather than secondary forest.

Example Box 5.1 Example Carbon Penalty

A C-Sink Manager in tropical Africa plans to afforestation a 1-hectare Management Unit (MU). The MU is situated on sloping land, and swift afforestation is crucial for the preservation of the topsoil. When verifying the land use history using satellite images and global forest watch data sets, it was revealed that until three years ago, the Management Unit was covered with young secondary forest.

As per the baseline land use regulations of the Global Tree C-Sink, the C-Sink Manager can proceed immediately with the afforestation activities within the framework of a certified Tree C-Sink project. However, before the C-Sink can be registered, the project activity must recover 30% of the previously lost forest.

A young (<20 years) secondary forest in a moist climate in Africa will store on average 100 t dry matter biomass per hectare (Annex 2), presenting a C-Sink of (100 t biomass * 50% C-content * (44/12) =) 183 t CO_2e per hectare.

The forest established by project intervention must reach 30% of this benchmark carbon stock, before all additional carbon sequestration can be registered. The first (183 t CO2e * 30% =) 55 t CO_2e per hectare compensates for the loss of the former forest and must not be registered as an additional C-sink.

Once this benchmark is passed, the Global Cooling Service generated from the sequestration of the 56th t CO_2e and beyond are accepted as additional and can be certified and valorised.

Those rules about the land use baseline are set to avoid incentivizing the logging of natural forests while swift afforestation of idle lands. Ultimately, we anticipate that the entire global forest carbon will be registered, obligating governments to ensure a net increase in forest coverage that sustains a rich level of biodiversity. As we work toward this vision, we are committed to bolstering the broader objective of enhancing global forest coverage in high biodiversity and net primary production (NPP) by implementing robust certification methods.

Conversion of monoculture forest or perennial agricultural plantations:

For the project type "conversion of monoculture forest plantation or perennial agricultural plantations" the baseline vegetation can be removed (harvested) before the establishment of the Tree C-Sink project. Monoculture plantations and agricultural production systems are not considered as "forest" in the baseline scenario and no carbon penalties will be applied to the established Tree C-Sink project.

5.1.1 No displacement of settlements, agricultural or pastoral activities

While tree planting projects can be harmoniously incorporated into agricultural or urban settings, they must not result in the relocation of settlements or the disruption of agricultural and pastoral activities. **Avoiding the replacement of settlements, agricultural- and pastoral activities is the most effective mechanism to avoid carbon-leakage, following the project establishment.** Abandoned or unutilized degraded land shall be used for tree planting projects. The C-Sink Manager may also integrate agricultural and pastoral activities into the MU in form of agroforestry, silvo-pastures, and designated grazing areas or make other sections of the land available for agricultural and pastoral purpose. It's crucial that tree-planting projects do not negatively impact the livelihoods of the local population.

5.1.2 Conservation areas and indigenous territories

In general, project areas should not be located within designated conservation zones, national parks, or indigenous territories as determined by nationally recognized authorities. This precaution ensures the protection of natural habitats and the rights of local communities from commercial encroachments.

However, there are specific exceptions:

- **Restoration within conservation areas or national parks:** Tree planting projects can be initiated within conservation zones or national parks if the primary objective is ecological restoration. In such cases, the C-Sink Manager must collaborate with the relevant regional or national authority or secure written authorization, such as a formal agreement, to conduct planting activities within these areas. It's imperative that only native or naturalized tree species are used for such afforestation initiatives.
- **Projects within indigenous territories:** Tree planting can proceed within indigenous territories, provided there is explicit written consent from the recognized indigenous authority, for instance, the village leader. Moreover, it is essential that indigenous communities are involved in the project as empowered stakeholders and benefit from the project.

5.1.3 Permanent grassland

Permanent grasslands, such as the Guinea savanna, play a significant role in carbon sequestration. Unfortunately, many of these grasslands worldwide face the threat of conversion into agricultural lands, which may involve practices like invasive tillage that can release significant amounts of stored carbon. From a climate perspective, introducing trees to these grasslands is preferable over such agricultural practices.

However, there are specific guidelines to follow when introducing trees into these natural habitats:

- **Biodiversity ranking:** Tree planting initiatives on natural grasslands are obligated to meet at least a Level II biodiversity ranking as described in chapter 3. This ensures that the project not only focuses on carbon sequestration but also considers the rich biodiversity of these landscapes.
- **Silvo-pastoral systems:** Planting densities are recommended at up to 200 trees per hectare. This approach can transform grasslands into silvo-pastoral agroforestry systems where both trees and grazing animals coexist, promoting both ecological and economic sustainability.
- **Flexibility in planting density:** While the recommendation stands at 200 trees per hectare, higher densities can be considered, depending on the specific goals of the project and the ecological considerations of the region.

In conclusion, while tree planting in grasslands is encouraged, it's vital that such initiatives are carried out with a balanced perspective, emphasizing both carbon sequestration and biodiversity preservation.

5.2 Wetlands

Globally, soils are a substantial carbon reservoir, holding over 2,500 Gt of carbon. This vast store is split between the organic carbon pool, which is shaped by a balance between organic matter input and mineralization, and accounts for over 1,500 Gt, and the remainder is comprised of carbonates and elemental carbon. It's notable that this organic carbon pool surpasses the global forest carbon pool – which ranges from 400-600 Gt – by three times. However, this organic reservoir is vulnerable to degradation. Should there be a disruption in the equilibrium between organic input and mineralization due to suboptimal land management, significant carbon loss may ensue (Lal 2008; FAO, 2022).

The highest concentrations of organic carbon are typically found in wetlands – areas saturated with water – and areas that were historically wetlands but have since been drained. Notably, these active or previously active wetlands, which necessitate drainage (or the prevention of rewetting) for any form of cultivation, are not considered eligible for projects under the current guidelines.

Draining these soils for cultivation, or avoiding their rewetting to maintain continuous cultivation, results in a project scenario with greater emissions compared to a baseline where the soil remains undisturbed or is actively rewetted.

Specifically, two soil categories are deemed ineligible and must not be incorporated into certified projects.

- **Histosol:** Histosols are characterized by upper horizons enriched with significant quantities of organic matter or peat, which can be several meters thick. They predominantly form under conditions where oxygen is depleted due to prolonged water saturation. These soils encompass peatlands and swamps, including those that have been drained.

- **Gleysol:** Gleysols are mineral soils influenced by groundwater, typically found in depressions and flat lowland terrains. In these soils, groundwater affects even the upper 50cm of the topsoil. Over time, Gleysols have the potential to evolve into Histosols.

For classification purposes, the Global Tree C-Sink employs the international soil taxonomy outlined by the World Reference Base (WRB) for Soil Resources and FAO. It's worth noting that other national classification systems might utilize synonymous terms. Refer to Figure 2 for an illustrative soil map showcasing soils according to both the FAO and WRB soil taxonomy systems.

Tree planting projects on coastal Gleysols, particularly in tidal zones, may qualify for mangrove restoration projects, yet remain subject to case-by-case evaluation. The possibility of tree planting in rewetted Histosols, using paludiculture practices (cultivation in undrained soils), is currently under review and might be incorporated in the forthcoming revision of the guidelines. Active drainage activities or the deliberate reduction of the groundwater table through the planting of high water-demand tree species, such as Eucalyptus, are strictly prohibited.

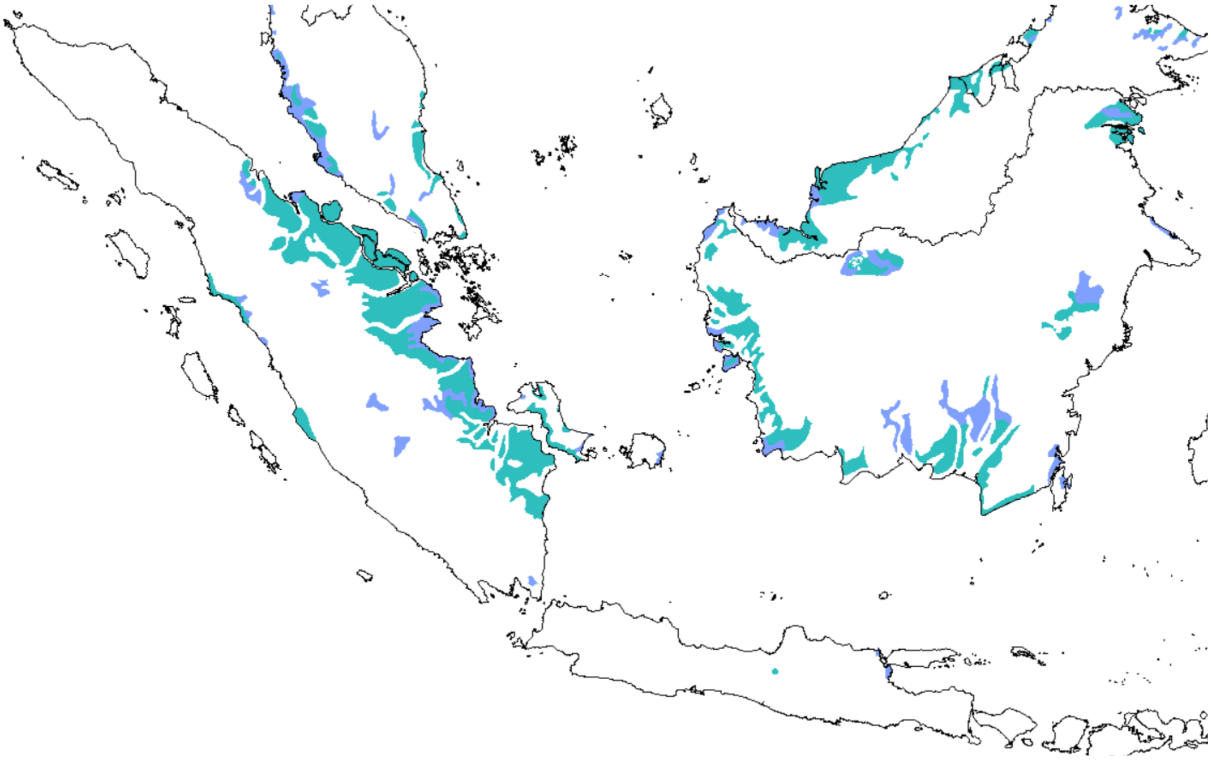

Figure 2: Distribution of Gleysols (blue) and Histosols (green) spreading over the Indonesian Islands of Sumatra, Java and Kalimantan (Borneo). Excerpt derived from the World Harmonized Soil Database (FAO, 2008)

5.3 Land Ownership

The land rights for the area designated for the project (e.g., the management unit) must be clearly established. This can typically be demonstrated with a certificate of land ownership, land lease contract, or land concession contract[8]. Only a stable land tenure can secure the sustainability of the project.

Undertaking planting activities on the land must comply with national laws, and the C-Sink Manager must ensure this legal status is maintained.

Land can be leased from an individual, a private enterprise, a local community, or the state. The land lease contract duration should be at most 100 years. When leasing from an individual or a local community, the maximum allowable contract length is 60 years. This shorter duration for private individuals and local communities is set to uphold their sovereignty. All lease agreements

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[8] If the management unit is owned by one landowner or is subject to the same lease/concession contract, one land certificate is sufficient. If the management unit is owned by multiple landowners, individual certificates must be provided. For smallholder farmers managing units less than 5 hectares who might not possess official land certificates, context-specific alternatives can be accepted. This could include evidence of land-related tax payments or a letter from the village leader confirming customary rights.

must honor prevailing local land lease rates, and the identity of the landowner must be properly documented.

The C-Sink Manager must either

a) own the land that is subject to the project, or

b) hold a concession or lease contract for the land, or

c) hold a contract with the owner of land and trees, or a local organization representing the owner of the land and the trees, defining the use of right including the valorisation of climate services generated by the trees.
Contracts should stipulate a benefit-sharing ratio, facilitating a partial transfer of profits from tree products and GCS to the landowner and workers employed in the project.

5.4 Free, Prior and Informed Consent

If the C-Sink Manager is not the landowner, the C-Sink Manager must secure a written and signed Free Prior Informed Consent (FPIC) from the landowner. This document must confirm the landowner's knowledge of the project's specifics, including its location, goals, potential revenue, and time span. The FPIC can be incorporated into the lease or right-of-use agreements. Should the landowner be unable to read or write, appropriate assistance must be furnished.

6. Work Safety and Social Safeguards

All workers directly employed by the C-Sink Manager must receive written information or practical training detailing potential risks associated with forest management, harvesting operations, wood processing, and transportation. This information should encompass guidelines on power tool handling, fire prevention, the utilization of personal protective equipment, and, if applicable, pesticide use. For workers directly employed by the C-Sink Manager, the supply and correct use of personal protective equipment must be ensured.

Work safety and fire protection measures must adhere to local and national regulations across the entire chain of custody, from forest management to wood processing and transportation. Each stakeholder is accountable for upholding relevant fire protection and safety guidelines within their area of operation. While the C-Sink management should advocate for these measures at all stages, they are not responsible for non-compliances that occur either downstream or upstream (e.g., in the event of an accident involving a forester on their private land or workers sub-contracted by local partner organisations of the C-Sink Manager).

The C-Sink Manager must describe potential risks to directly and indirectly employed workers and outline a strategy, adequate to the local project context, to improve the work safety. The risk-mitigation strategies need to be presented in the PDDs see chapter 10.1 and its implementation will be verified during the on-site audit.

Managed regeneration or afforestation projects must ensure they do not negatively impact local communities and indigenous groups. These communities and groups ought to be actively involved in decision-making processes, ensuring their recognition and participation as fully empowered stakeholders. Their engagement should span from project planning to hold land rights, land access rights, employment opportunities—from labor roles to board positions—as well as access to forest products. They should also benefit from land lease agreements, timber sales, and climate services wherever feasible. A strategy for local stakeholder participation and engagement must be presented in the PDDs (c.f., Chapter 10.1) and its implementation will be verified during the on-site audit.

Smallholders, local communities, and indigenous peoples own or oversee approximately half of the world's forest and farmland (FAO, 2022). Ensuring Free, Prior, and Informed Consent (FPIC) and genuine participation from these groups is paramount for the successful scaling of sustainable landscape restoration strategies. This approach not only addresses global climate change but also promotes biodiversity.

7. Carbon Expenditures

For the effectiveness of any C-Sink as a tool in mitigating climate change, it's essential that the net C-Sink is quantified, certified, and recorded in the Global C-Sink Registry.

The emissions generated in the creation of a C-Sink are termed as carbon expenditures. All such carbon expenditures must be meticulously documented for each project activity, as detailed in Chapter 7.1. These expenditures are then converted into CO_2 equivalents using the emission factors listed in Table 4.

These carbon expenditures are then registered as the project's emission portfolio within the Global C-Sink Registry. For every certification standard falling under the Global C-Sink umbrella, a distinct offset of the emission portfolio - encompassing all the recorded carbon expenditures - is mandated prior to a C-Sink's inclusion in the Global C-Sink Registry. Therefore, every certified and recorded C-Sink signifies a **net removal of CO_2** from the atmosphere.

7.1 Project Emission Portfolio

- Project emissions[9] should be recorded per C-Sink Unit; however, it can also be recorded per Management Unit and proportionally assigned to the C-Sink units within. **Land preparation**: If the project adheres to the land eligibility criteria outlined in Chapter 5 and the sustainable management guidelines mentioned in Chapter 4, (which includes the conversion of bushland, but no deforestation, no drainage, no inversive tillage, no burning, etc.), then significant emissions from land-use conversion are unlikely. The C-Sink Manager is only required to record fuel consumption (diesel and gasoline) and electricity usage during the land preparation and planting stages. This also encompasses the transportation and handling of materials, such as seedlings, saplings, and debris. **The carbon content of removed biomass does not constitute a carbon expenditure[10].**
- **Forest management:** The C-Sink Manager is obligated to record fuel consumption (diesel/gasoline) and electricity usage throughout forest management activities. This includes tasks such as trimming, pruning, thinning, liberation, mowing, spraying, irrigation, transportation/ travel, and monitoring surveys.

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[9] Given that additional emissions occur annually, a continuous reporting of project emissions (comparable to scope 1-3 company emissions) is required instead of a one-time "product" lifecycle assessment.

[10] Management principles as stipulated in chapter 4 and chapter 5 ensure that only minor quantities of biomass carbon is lost form the terrestrial system during land preparation. Biomass carbon bound in bushland is considered a fast-turnover pool which is quickly replaced and replenished by the project's activity.

- **Fertilization:** The project needs to record the total quantity of mineral/synthetic nitrogen (N), phosphate (P), and potassium (K) – commonly referred to as NPK – fertilizers, as well as any lime applied within the project area[11].
- **Harvest:** The project is required to record the fuel consumption (diesel/gasoline) and electricity used during harvesting operations, which includes the operation of chainsaws, full harvesters, transport trucks, bulldozers for road construction, and the like.
- **Transportation:** Documentation is necessary for the transportation of workers to the project site, along with associated fuel (diesel/gasoline) consumption. This includes workers for forest management and monitoring activities.
- **Electricity:** C-Sink Managers are urged to transition from fuel-powered machinery to those operated by electricity or renewable fuels. Any consumed electricity should ideally be sourced from renewable means, and evidence of its origin is essential. All electricity and renewable fuels consumed must be accurately documented, inclusive of their carbon footprint. The use of electricity generated from renewable sources, such as solar or wind, should be explicitly reported.

Table 4: Emission conversion factors for scope 1, scope 2 and fertilizer usage

Input	CO2 equivalent	Reference
1 l diesel	0.00269 t CO_2e	EPA (2023)
1 l gasoline	0.00235 t CO_2e	EPA (2023)
1 kg synthetic N (in N fertilizer)	0.01 t CO_2e	Walling and Vaneeckhaute (2020)
1 kg P2O5 (Ammonium phosphate)	0.0089 t CO_2e	Walling and Vaneeckhaute (2020)
1 kg P2O5 (single super phosphate)	0.001 t CO_2e	Walling and Vaneeckhaute (2020)
1 kg P2O5 (triple super phosphate)	0.0016 t CO_2e	Walling and Vaneeckhaute (2020)
1 kg K2O	0.0025 tCO2e	Walling and Vaneeckhaute (2020)
1 t industrial lime	0.45 t CO_2e	EEA (2016)
1 kWh	*variable* $tCO_2e\ kWh^{-1}$	Use national factor
1 t km transport	0.111 t CO2e t km^{-1}	UBA (2022)
When contractors are employed for the transportation or operation of heavy machinery, fuel consumption might not always be directly recorded. In such instances, documenting the operational hours is essential. As a reference, one hour of operation for a tractor or truck equivalent is estimated to consume 12 liters of diesel.		

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[11] Consumables, such as fertilizers, would typically be classified under Scope 3 emissions. Nevertheless, due to their notable impact on the project's overall emissions, the are addressed here as a distinct category, excluded from the 10% allowance for Scope 3 emissions.

The primary scope 1 and 2 emissions listed above, should be recorded and documented on a monthly basis, using tools such as journey logbooks for vehicles and fuel purchase receipts for other machinery. These records are then aggregated to determine the annual project emissions. As per equation 1, an additional safety margin of 10% is included to account for miscellaneous scope 3 emissions.

Equation 1

$$\boxed{\text{Carbon Expenditures }(\text{tCO}_2\text{e year}^{-1}) = (\text{annual scope } 1 + \text{ scope } 2 \text{ emissions }(\text{tCO}_2\text{e})) * 1.1}$$

7.2 Ex-Post Documentation and Reporting of Carbon Expenditures

Using the template **"Carbon Expenditures"**[12] as provided by Carbon Standards the C-Sink Manager must provide the following information on the following subjects:

- **Emission Portfolio:** C-Sink Managers must aggregate, and document the annual carbon expenditures (per C-Sink unit) quantified ex-post in $\text{tCO}_2\text{e year}^{-1}$. Where applicable, this documentation must be amended, receipts/journey logbooks, and a clear monthly breakdown of carbon expenditures. While only the aggregated emission portfolio as per Equation 1 is uploaded to Carbon Standards via an API interface, the C-Sink Manager must retain the detailed emission portfolio documentation for a minimum of 10 years. The comprehensive documentation must be provided to the certifier during the annual audit.

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[12] Once Carbon Standards introduces the Global Tree C-Sink Tool, emissions will be logged online by C-sink unit and year. At that point, the tool will incorporate the emission conversion factors, eliminating the need for the C-Sink Manager to perform any additional calculations.

7.3 Carbon Leakage

Carbon leakage refers to emissions caused by activities that were spatially replaced by the carbon project activity. For example, an afforestation project displaces cattle ranging to a place where forests are cut down to establish new pastures. Emissions from downstream deforestation are commonly considered leakage to the initial carbon project.

The key mechanism to avoid carbon leakage is to avoid the displacement of settlements, agriculture, and pastoral activities.

To this end the Global Tree C-Sink guideline stipulates baseline land-use requirements aiming to minimize and avoid carbon leakage (c.f., Chapter 5.1). Tree C-Sink projects should be established on abandoned, unutilized, degraded land. Projects must not displace settlements or agricultural- or pastoral activities. Where this cannot be guaranteed, the Global Tree C-Sink opens possibilities to integrate agricultural- and pastoral activities into the projects by means of agroforestry, silvopasture, or designated grazing areas.

Carbon leakage can hardly be tracked and quantified empirically, as system boundaries are open, and causalities are unclear. Temporal boundaries to assess and document carbon leakage may extend beyond the lifetime of the actual Tree C-Sink project, while in a world of trans-border trade in products, fuel, food, and feed, the spatial boundaries are global.

The Global Tree C-Sink follows a strategy in which the project design minimizes carbon leakage as far as possible, creating project scenarios that are mutually beneficial for all stakeholders.

Beyond that, pro forma paperwork attempting to prove the absence of carbon leakage is not required.

8. Ecological Additionality

Once all terrestrial carbon sinks have been registered, "additionality" refers to an increase in the net carbon sequestered within the terrestrial system. The boundaries for assessing a C-Sink system might be demarcated at regional or national levels, yet "additionality" unvaryingly denotes a boost in the overall carbon store of the chosen reference system.

However, pinpointing "additionality" becomes ambiguous when considering spatially constrained projects, such as afforestation spanning several hundred hectares or the incorporation of a few thousand tons of biochar. The criteria for regulatory additionality (where, for instance, an afforestation initiative is only deemed “additional” if not already dictated by law) and financial additionality (where a C-Sink project is considered “additional” solely if it's financially unviable without the additional influx of revenue from carbon credits) can unintentionally obstruct the swift implementation of C-Sinks.

The scrutiny of "additionality" in terms of carbon capture and storage capacity relative to a baseline scenario, as stipulated in chapter 5, remains both a pragmatic and an essential approach to Global Tree C-Sink certification.

The Global Tree C-Sink is dedicated to advancing afforestation initiatives that exhibit exceptional environmental integrity. Beyond ensuring carbon additionality relative to the baseline scenario, Global Tree C-Sink emphasizes and certifies the **ecological additionality** of each project.

To meet this criterion, projects must demonstrate additionality in at least one of the following ecological parameters:

- The project exhibits a clear deviation from local customary practices by establishing more sustainable management systems (for instance, adopting agroforestry techniques in place of slash-and-burn methods).
- The tree planting initiative directly contributes to significant environmental improvements in the vicinity (examples include enhancing biodiversity through the introduction of diverse tree species, trees planted for water conservation, mitigating erosion, preventing landslides, or serving as firebreaks).
- Evidence suggests that, in the absence of the tree planting initiative, alternative undertakings detrimental to the environment would have transpired (such as establishing a monocultural palm oil plantation).
- Proof indicates a necessity for afforestation in specific areas, either to act as a protective buffer around national parks, to provide habitats for certain species (like gorilla sanctuaries), or to enhance various ecosystem services.

9 Exclusivity of the Certification

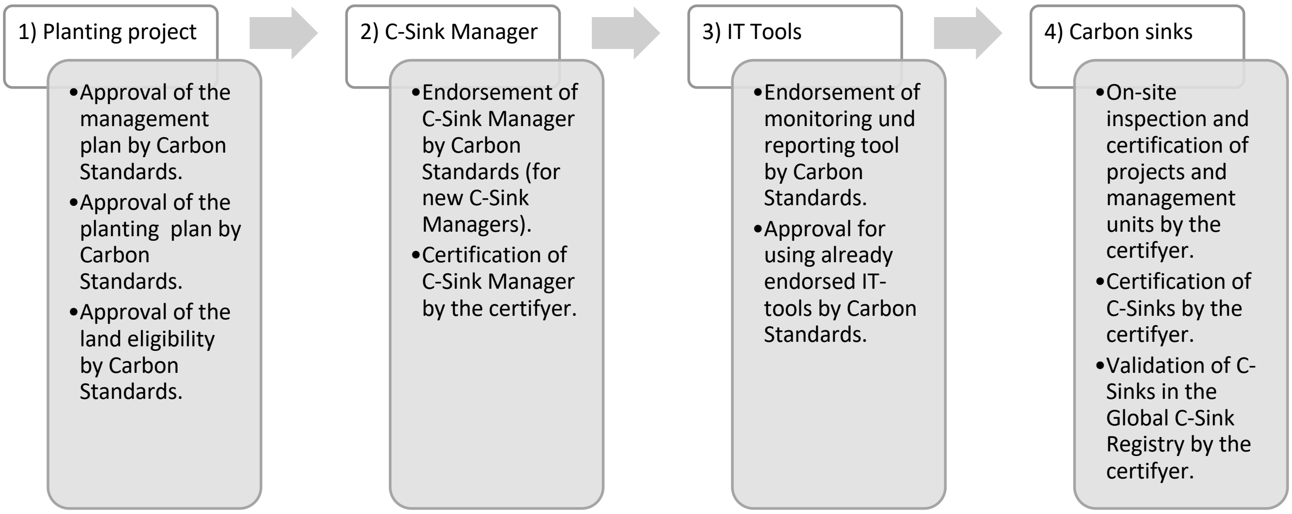
Areas certified under the Global Tree C-sink that comprise registered Management Units and C-Sink Units, including the trees managed within these spatial units, shall not concurrently hold CDR or C-sink certifications from other labels or standards. This prohibition extends to registering and valorizing the climate service provided by the respective area or trees. It further encompasses schemes targeting biomass carbon storage, soil carbon storage, and emissions from avoided deforestation. Conversely, areas and trees already registered or certified for their climate service, including a designation as a nationally determined contribution (NDC) of the country hosting the project area, are ineligible for certification under the Global Tree C-sink. If a C-Sink Unit is already designated as an NDC of the country hosting the project area, the C-Sink Unit can be certified, but it must be registered in such a way that trading the C-sink and its climate service is not possible.

This exclusivity must be guaranteed by the Tree C-Sink Manager and will be verified by the Certifier. Furthermore, all spatial data of certified C-Sink Units are publicly accessible in the Global C-Sink Registry.

Those rules of exclusivity in the certification and registration of C-sinks and their climate services, meaning exclusive certification under the Global Tree C-sink and documentation solely in the Global C-Sink Registry, are crucial to prevent double-counting of climate services.

10. Certification

The certification procedure is comprised of four basic components (chapter 10.1-10.4), as illustrated in Fig. 3. A minimum of three months is necessary to finalize the certification process. However, the duration could extend substantially based on various factors such as the punctuality, completeness, and accuracy of the data supplied by the C-Sink Manager, the prevailing dMRV applications, and the scope of the projects.



1) Planting project

- Approval of the management plan by Carbon Standards.
- Approval of the planting plan by Carbon Standards.
- Approval of the land eligibility by Carbon Standards.

2) C-Sink Manager

- Endorsement of C-Sink Manager by Carbon Standards (for new C-Sink Managers).
- Certification of C-Sink Manager by the certifyer.

3) IT Tools

- Endorsement of monitoring und reporting tool by Carbon Standards.
- Approval for using already endorsed IT-tools by Carbon Standards.

4) Carbon sinks

- On-site inspection and certification of projects and management units by the certifyer.
- Certification of C-Sinks by the certifyer.
- Validation of C-Sinks in the Global C-Sink Registry by the certifyer.

Figure 3: *Schematic overview of 4 main steps in C-Sink Certification. 1) Approval of the tree planting projects by CARBON STANDARDS 2) Endorsement and Certification of the C-Sink Manager, 3) Endorsement or approval of digital monitoring and verification tools, 4) Certification of management units and registration of C-Sinks.*

10.1 Project Design Documents (PDD)

Using the PDD template **"Management Plan"** as provided by Carbon Standards the C-Sink Manager must provide information on the following subjects:

- **Project type (c.f. cp.1):** Appropriate selection form Table 1 (Afforestation, Plantation, Agroforestry, Urban, Natural Regeneration, Conversion of monoculture plantation)
- **Project location and spatial organization (c.f. cp.1):** Project location, georeferenced and mapped documentation of management units and associated C-Sink units indicating location, owner, size, and unique ID of the units.
- **Carbon accounting (c.f. cp.2):** Description of which accredited dMRV application is utilized by the project (refer to Chapter 10.3 for the endorsement process of a new dMRV application). Detailed schedule for monitoring the project area. Description elucidating the process of transmitting data between dMRV application and the Global C-Sink Registry. Description of training procedures for dMRV application operators incl. standard operating procedure and handling of challenges like poor GPS signal or internet connectivity issues.
- **Sustainable Management (c.f. cp.4):** Detailed description of land preparation including soil preparation, biomass removal, and retention of remnant trees, fertilization schedule, irrigation schedule, harvest schedule (including anticipated biomass utilization, fostering climate positive management),re-planting schedule, and risk-management.
- **Internal Control System (c.f. cp.4):** The C-Sink Manager is also obliged to present the certifier with a blueprint of an internal control system (ICS). The ICS plays a pivotal role in ensuring and upholding the project's quality including tree survival rate and the integrity of the collected data. This may be achieved through systematic quality checks, field visits, data sampling, resolution of conflicts of interest, or the imposition of potential sanctions if needed.
- **Strategy to uphold work safety (c.f. cp.6):** Strategy for fire prevention, protection when using pesticides, and further strategies to promote work safety.
- **Strategy for local stakeholder engagement (c.f. cp.6):** Strategy to promote local stakeholder engagement and benefit.

Using the PDD template **"Planting Plan"**[13] as provided by Carbon Standards the C-Sink Manager must provide information on the following subjects:

- **Tree composition (c.f. cp.3):** A detailed list that includes the number and species of trees planted. Information on species origin, climate resilience, non-invasiveness, and IUCN status.
- **Biodiversity and conservation related management (c.f. cp.3)**: Detailing the location, size, and composition of the conservation area. Detailing the employed tree management including planting pattern, fertilization, plant protection, and harvest procedure to evaluate all indicators listed in Table 3.
- **Map (c.f. cp.3):** Illustrating the anticipated planting pattern in a georeferenced map or satellite picture.
- **Ecological additionality (c.f. cp.8):** The C-Sink Manager is required to prepare a comprehensive statement detailing the ecological additionality of the project.

Using the PDD template **"Land Eligibility Statement"** as provided by Carbon Standards the C-Sink Manager must provide information on the following subjects:

- **Land use history (c.f. cp.5):** Providing comprehensive description detailing the land use history over the decade leading up to the project's inception. Including geo-referenced satellite imagery of the project location, clearly delineating the planting areas. Each of these areas should be marked as a distinct polygon, complete with a unique ID and its corresponding surface area in hectares. It's imperative that all submitted satellite images are sourced from a reliable and verifiable public database. Acceptable sources include, but are not limited to, Sentinel or Landsat provided by institutions like Copernicus, NASA, ESA, DLR, FOSSGIS, EOS, and NOAA. Reputable private sources, such as excerpts from Global Forest Watch, are also valid. The images must give a visual account of the project area or management **unit both in the present day (one year before project start, as per data availability) and a decade before the auditing procedure. Further, a geo-referenced excerpt from the global forest watch database, covering the decade before project establishment must be provided.**
- **Soil map (c.f. cp.5):** Providing a georeferenced soil map of the project area/ management unit. This map must clearly indicate the management units, with each labeled as a unique polygon showcasing its distinct ID and the respective surface area in

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[13] The submitted planting plan must meet all principles as per biodiversity Level I. If the single-tree tracking approach is utilized for C-accounting: No further analog reporting is needed in the subsequent years after the planting. The survival rate and species mix will be automatically documented via the dMRV single tree tracking system. For other C-accounting methods: The C-Sink Manager must update the planting plan at a minimum of every 5 years. The updated plan must be submitted for verification.

hectares. This soil map must be sourced from a reputable and verifiable public database. Acceptable sources include but are not limited to: Harmonized World Soil Database by FAO, Soil Map of The World by UHH, Global Soil Map by ISRIC, and the Digital Soil Map of the World by ESDAC. Date of data publication should be more than 20 years before the date of project establishment. During the certification process, a auditor may also undertake additional on-site soil characterization.

- **Verifiable proof of established land rights (c.f. cp.5)**: Certificate of landownership by C-Sink Manager or contractual partner. Alternative concession permit granted by state or regional authorities.
- **Contracts (c.f. cp.5):** In instances where the C-Sink Manager is not the direct landowner, a valid contract specifying lease or use rights must be available.
- **Free prior informed consent (c.f. cp.5):** If the FPIC is not incorporated into the contract, the C-Sink Manager must possess a signed document confirming the FPIC from the legitimate landowner. This document will be scrutinized by the auditor during the review process.

All PDDs, excluding supplementary files such as land certificates and contracts, will be made publicly available through the Global C-Sink Registry.

10.2 Endorsement of C-Sink Managers

The scope of afforestation projects can differ significantly. While expansive projects often achieve cost efficiency on a per ton basis for removed CO2, more compact and decentralized initiatives often boast superior quality due to enhanced botanical diversity and more thorough engagement of local communities. The Global Tree C-Sink offers a certification avenue for projects of every size. For both reliability and cost efficiency Carbon Standards endorses local organizations to act as C-Sink Managers. These managers spearhead project establishment, training sessions, data collection, and ongoing project oversight, all in line with the Global Tree C-Sink guidelines.

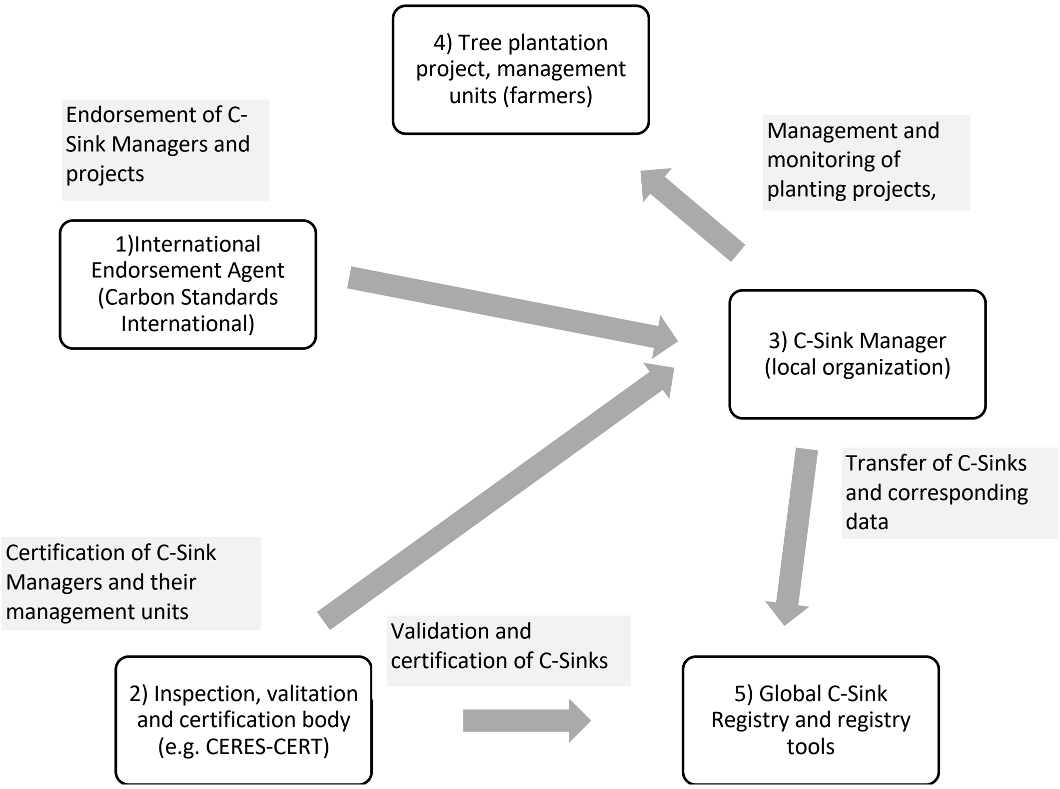

Figure 4: The Global Tree C-Sink is organized as a five-party structure. 1) The international endorsement agent (Carbon Standards International), 2) The inspection, validation and certification body (e.g. CERES-CERT), 3) The C-Sink Manager (local organization), 4) The tree plantation projects with their management units and C-Sink units, 5) The Global C-Sink Registry and registry tools. In some specific context, national carbon registries may present an additional party.

The individual or entity designated as the C-Sink Manager must be legally registered in the project's host country, thus possessing a national tax ID.

It's preferable for the C-Sink Manager to be a local organization, consistently present and deeply integrated within the project's host country. However, this isn't a strict requirement. If the C-Sink Manager isn't continuously present in the project's country, a solid partnership with a local entity (such as a local NGO) is imperative. This partnership should be cemented with a legally binding contract, annually verified by Carbon Standards. Having a local ally is essential for effective project management, encompassing tasks like on-the-ground visits, farmer education, and tree oversight.

If the C-Sink Manager is located abroad, a specific contractual legal framework with the local manager must be established. The legal framework is part of the annual endorsement verification process by Carbon Standards.

Potential project managers can formally petition Carbon Standards for recognition as C-Sink Managers.

A C-Sink Manager is officially certified upon the successful completion of certification procedures outlined in steps 9.1 (successful project planning) to 9.2 (successful endorsement by Carbon Standards).

10.3 Endorsement of New dMRV Technologies for Carbon Accounting

- Endorsed digital Monitoring, Reporting and Verification (dMRV) technology, as recognized by the Carbon Standards technology list (Table 2), may be utilized.
- For the endorsement of innovative C-accounting methods and technologies, a detailed outline of the new method or technology should be submitted to Carbon Standards
- When seeking endorsement for a new technology that aligns with a measurement approach already detailed in Annex I, compliance with the specifications set out in Annex 1 must be demonstrated.
- For endorsement entirely novel measurement approaches, a comprehensive description of the approach, along with its foundational quality and performance requirements, must be formulated by the applicant in collaboration with Carbon Standards.
- To gain endorsement for a specific technology that aligns with this new approach and aligns with the requirements as per chapter 2, a detailed explanation, inclusive of relevant references, must be shared with Carbon Standards.
- Validation reports, ensuring that the accuracy of the new measurement technique remains ≤ 10% deviation when cross-referenced against ground samples, are requisite. The extent of the ground sample (number of replicates/area) will be defined on a case-by-case basis, contingent on the measurement method.
- The technology's range of applicability (whether it pertains to specific species, regions, projects, etc.) needs to be explicitly articulated and justified.
- Carbon Standards must be given a thorough presentation of the technology/application/platform’s hardware and software components. Absolute transparency with Carbon Standards is essential when accrediting new technologies. To safeguard the intellectual property of the C-Sink Manager, non-disclosure agreements will be executed.
- The prerogative to request additional on-field demonstrations and validation of the C-accounting technology during in-person field evaluations remains with the certifier.

10.4 C-Sink Certification

Upon the approval of the aforementioned documents and technologies and the physical initiation of the project, the certifier will conduct on-site audits. Audits may be conducted online in justified exceptions. The decision to opt for online or on-site audits remains at the discretion of the certification body.

For every C-Sink Manager, these on-site audits will encompass each management unit at a minimum of once every five years (first audit in the year of implementation). Furthermore, a random sample comprising at least 5% of the management units will undergo annual inspections.

Additionally, the C-Sink Manager is required to supply the certifier annually with new aerial imagery, which must include both a timestamp and geolocation. These **photographs or films** must be captured by a drone or technology delivering equivalent graphic quality at an altitude no greater than **100m** above the canopy, covering the whole Management Unit. Up-to-date footage will be displayed in the Global C-Sink Registry. The certifier reserves the right to individually conduct additional drone flights at times of on-site audits.

Figure 5: *Aerial photograph taken at 250 m altitude. Yellow square indicates an area of one hectare for reference. (Source Googe Earth, 2023)*

From any management unit that underwent successful inspection and where no non-conformities were identified (i.e., project certified), certifiable C-Sinks are to be quantified ex-post using an accredited dMRV C-accounting method. Such accredited methods calculate the stored CO_2e drawing from empirical data with high spatial and temporal precision.

While annual monitoring and verification is recommended, it must be undertaken at a minimum every five years. However, due to the exclusive allowance of ex-post certification, annual dMRV becomes essential for sustained value generation, especially when prepurchase agreements aren't in place.

Data quality is maintained through several measures: the accreditation of the dMRV technology, the competency and training of the operator, and the robustness of the internal control system. Furthermore, a random sampling of a minimum of 1% of the incoming data must be inspected by the C-Sink Manager, and data samples should be readily accessible to the certifier when solicited.

A C-Sink's is only certified once two conditions are met: A) its entry is confirmed in the Global C-Sink Registry, and B) the emission portfolio, which encompasses all carbon expenditures measured and reported for the corresponding monitoring period, is offset via the retirement of persistent C-Sinks.

11. Data Availability, Usage, and Rights

Carbon accounting technologies

For the accreditation of new C-accounting dMRV technologies, full transparency is mandated with Carbon Standards. This encompasses the operational principles of the technology and all foundational training datasets. This information will remain confidential, respecting that it constitutes the intellectual property of the C-Sink Manager or other designated service providers.

Carbon sinks

Every certified C-Sink must have its **(1) type, (2) size, (3) geolocation, and (4) timestamp of measurement recorded in the Global C-Sink Registry.** This is facilitated via an API interface bridging the project's own database and the Global C-Sink Registry. Ther certifier verifies and validates all inputted data before activating the C-Sink. The Global C-Sink Registry, operating under a non-profit model, is dedicated to recording details such as type, location, magnitude, proprietorship, durability, and status (either active or retired) of all C-Sinks in a centralized, safeguarded, transparent, and publicly accessible platform. Apart from data storage and display, the Global C-Sink Registry doesn't possess any additional rights in regard to the registered C-Sinks.

Tree growth data and models:

For the progression of scientific understanding, tree growth and carbon assimilation data employed to formulate allometric equations should be made available to the broader scientific community and safeguarded under a Creative Commons License. A duplicate of this primary tree growth data is to be forwarded to a central database overseen by either the Ithaka Institute or the Global Carbon Register Foundation, or both. This database will be established in 2024 by the Ithaka Institute for Carbon Strategies and the Swiss Carbon Register Foundation. The objective is to aggregate and systematize the data that's garnered worldwide from all projects certified under the Global Tree C-Sink guidelines. To protect individual data sources, the data will be anonymized prior to its release. Only registered scientific users will gain access, and they must adhere to the terms set by the Creative Commons License.

12. Valorisation of Dynamic Biomass-Based C-Sinks

Projects that are established and operate in alignment with the principles set forth in the Global Tree C-Sink guideline have the potential to generate certified C-Sinks once all carbon expenditures have been offset.

However, it's crucial to understand that to truly neutralize the impact of fossil CO2 emissions, a persistent C-Sink of equivalent magnitude is necessary, something which living biomass alone cannot offer. While tree-based C-Sinks serve a pivotal role, they are inherently dynamic and of temporary nature and cannot be relied upon to offset CO_2 emissions. Still, biomass-based C-Sinks present a timely intervention to counteract the immediate annual global warming effects of greenhouse gas emissions and to avoid tipping points in the climate systems (Armstrong-McKay et al., 2022).

Recognizing these dynamics, the Global Tree C-Sink adopts a flexible and temporal approach to biomass-based carbon removal accounting. This methodology facilitates the proper valuation of tree-related climate benefits, which is termed as Global Cooling Services.

12.1 Global Cooling Services

Tree-based C-Sinks have a dynamic nature. Their carbon stock increases during their growth, but the accumulated carbon is vulnerable and can be released at any point due to unforeseen events such as fires, pests, natural disasters, or anthropogenic activities. Furthermore, post-harvest practices play a significant role in determining whether this carbon remains sequestered or is released back into the atmosphere.

Given the temporal and uncertain nature of tree-based C-Sinks, guaranteeing long-term carbon sequestration exceeding a millennium is not feasible. This inherent unpredictability renders tree-based C-Sinks unsuitable to be marketed as CO_2 offsets. What should be recognized instead, is the immediate benefit and value they provide in terms of climate regulation, ecosystem services, and as part of a comprehensive strategy towards a sustainable and resilient environment.

The climate benefit of temporary C-Sinks is uniquely recognized and valued for its global cooling service (GCS). This GCS operates by counteracting the global warming impact triggered by specific GHG emissions over a defined duration, as detailed in the Global C-Sink guidelines (link).

Global Cooling Service metrics are quantified in units of t aCO2e (pronounced as " ton annually stored CO2 equivalent”. To clarify, 1 t aCO2e signifies the physical sequestration of carbon corresponding to the removal of 1 t CO2e from the atmosphere, sustained over an annual period. Thus, a C-Sink sequestering 100 t CO2e over a decade possesses the capacity to offset the global warming effect of a 100 t CO_2e emission for those ten years. After those ten years, the global warming effect of the emission is again produced if no other C-Sink is used to compensate the warming with an equivalent global cooling. This demonstrates the importance and continuous need for implementing and maintaining global cooling services.

The Global Tree C-Sink operates on a foundation of authenticity and evidence-based accreditation. Only after the CO2 has been conclusively extracted from the atmosphere, duly measured, and verified (ex-post), will the GCS be certified. This ensures the integrity of each certificate, safeguarding the trust of all stakeholders involved.

However, recognizing the financial constraints and challenges associated with afforestation and other C-Sink projects, provisions are available for C-Sink Managers. These managers can establish pre-purchase agreements or sell options linked to anticipated future GCS. Such arrangements can serve dual purposes: to secure the necessary initial capital for kick-starting the projects and to foster broader market engagement. It’s a forward-looking approach that balances the immediate financial needs of projects with the overarching goal of carbon sequestration and global cooling.

12.2 Pre-Purchase Agreements

Pre-purchase agreements form a critical component of the financial scaffolding that can support the early stages and ongoing management of C-Sink projects.

Definition and Basis: Pre-purchase agreements are essentially contracts where the buyer agrees to purchase a certain amount of GCS from a C-Sink project at a predetermined price, even before the GCS has been certified. These agreements hinge on "certified expected C-Sink curves," as outlined in chapter 2, which provide a forecasted trajectory of how much carbon the project is anticipated to sequester over time.

Risk Management and Duration: The dynamic nature of tree-based C-Sinks brings inherent risks, as the amount of carbon sequestered can be influenced by various unforeseen factors such as pests, fires, or other natural calamities. To manage these uncertainties and safeguard both buyers and C-Sink Managers, the Global Tree C-Sink recommends a prudent approach: limiting the duration of these pre-purchase agreements to a maximum of 10 years into the future. This decade-long span strikes a balance between giving projects the forward-looking financial assurance they need and ensuring that the commitments remain within a reasonably foreseeable time frame.

Benefits:

1. **Financial Security for Projects:** With funds secured in advance, projects can plan their activities better, ensuring the necessary resources are available for tree planting, maintenance, and monitoring.
2. **Attractive for Investors:** Buyers or investors get the advantage of locking in prices today for future GCS, potentially securing favourable rates while supporting climate action.
3. **Enhanced Trust:** By sticking to a 10-year window, both parties can make more accurate predictions and commitments, building trust in the system.

In conclusion, while pre-purchase agreements provide an essential financial instrument for the growth and sustainability of C-Sink projects, they must be approached with caution, foresight, and mutual understanding of the associated risks and rewards.

13. Downstream C-Sinks

The Global Tree C-Sink standard establishes guidelines for C-accounting and certifying dynamic tree-based C-Sinks, spanning from individual trees to expansive forest stands. The C-Sink certification within this standard focuses on the existing above and below-ground biomass (AGB & BGB) of living trees. Should a tree be felled or lost, it must be removed from the C-Sink Manager's tree database and the Global C-Sink Registry. Wood extracted from a Global Tree C-Sink project is considered climate-neutral.

When biomass is extracted from the system, such as through selective logging, the tree-based C-Sink diminishes (or the net increase per hectare decelerates). However, unless the biomass is used solely for energy, releasing all the sequestered CO2e, the carbon remains sequestered in stored wood, downstream wood-based products, or transformed products like biochar. These products can subsequently be certified as new temporary or even persistent C-Sinks. Retaining carbon originally assimilated by a tree in the terrestrial system via such downstream C-Sink is vital to maintain an overall climate positive management as stipulated in principle number 6, chapter 4 "Sustainable Management."

A single local organization can register as a C-Sink Manager under various guidelines. For instance, it might spearhead a tree planting initiative under the Global Tree C-Sink, produce biochar from wood residues within the framework of the Global Biochar C-Sink, and concurrently store carbon in the built environment as per the Global Building C-Sink guidelines.

Glossary

100%, 1000 year principle	To offset a CO_2 emission with C-Sinks, an equivalent amount of CO_2e (= 100%) must be removed from the atmosphere and stored for at least 1000 years. This requires instant removal of the total amount of carbon and ensuring uninterrupted storage for 1000 years.
Afforestation	Afforestation refers to the process of establishing a forest, or stand of trees, in an area where there is currently no forest cover as per the forest definition. Suitable land can be selected regardless of its canopy history; no waiting period is required.
Agroforestry	Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used in the same management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence (FAO, 2023).
Allometric Equation	Mathematical expression, resulting from a regression analysis between tree diameter and/or height of a tree (independent variable) and its total above ground biomass, typically in volume or mass (dependent variable). Allometric equations are generated from empirical measurements. Eligible allometric equations must be peer reviewed, species and climate zone specific, and endorsed by the standard holder (i.e., Carbon Standards International).
Carbon expenditures/ Emission portfolio	Carbon expenditures represent the greenhouse gas emissions associated with the establishment and maintenance of a C-Sink, essentially reflecting the carbon footprint of the C-Sink itself. These expenditures are tracked and reported on a monthly basis, using the CO2e metric. The carbon expenditures of a project are aggregated in the project's emission portfolio. The emission portfolio of any project must be offset before any tree carbon sink can be registered.
Certifier	The certifier (e.g., CERES-CERT) is an international agency, endorsed by Carbon Standards International. The certifier administrates and executes the auditing and accreditation of new dMRV applications, C-Sink Managers, and tree-planting projects according to the Global Tree C-Sink guidelines.
C-Sink	A C-Sink is the result of CO_2-removal from the atmosphere, its transformation into a storable form and consecutive carbon storage for a verifiably duration. C-Sinks are classified depending on their C-sequestration curve (i.e., the time-dependent function, describing the amount of C being

	sequestered in the C-Sink). A C-Sink is described as temporary if an increase, decrease or complete loss of the stored C (C-leakage) can be expected in the first 1000 years after its establishment (e.g., trees or soil organic carbon). A C-Sink can be described as persistent if no C-leakage can be expected in the first 1000 years after its establishment. (e.g., the PAC fraction of biochar or geological C storage).
C-Sink Manager	Is the entity responsible for organizing, managing, and monitoring tree planting projects, seeking certification under the Global Tree C-Sink. This manager must be accredited by Carbon Standards and bears the responsibility of submitting all essential information to the Certifier and Global C-Sink Registry. The individual or institution acting as the C-Sink Manager must be a registered juristic entity within the country of the project's location and possess a national tax ID. While it's recommended for the C-Sink Manager to be a local organization with a consistent presence and integration in the project's country, this is not strictly required. If the C-Sink Manager isn't permanently based in the project's country, a robust partnership with a local entity, such as an NGO, is essential.
Global C-Sink Registry	The Global C-Sink Registry is an independent, secure, digital database that records certified C-Sinks along with their corresponding C-Sink curves. This registry serves as a library for compiling C-Sink portfolios. Furthermore, it provides essential information on each C-Sink, such as its current status (e.g., whether it's available for sale or has been retired), the date of its CO2-removal, the establishment date of the C-Sink, and its geographical location. Such sector-specific, global or national C-Sink registers offer a comprehensive overview on contributions to Carbon Dioxide Removal (CDR). The Global C-Sink Registry is operated and hosted by the Swiss Carbon Register Foundation.
C-Sink unit	A C-Sink unit refers to a specific area, spanning up to 10 hectares, which can form either a part or the entirety of a management unit. Data related to carbon accounting is consolidated at the level of this C-Sink unit. The C-Sink derived from each of these units serves as the standard reporting format submitted to the Global C-Sink Registry.
Diameter at breast height (DBH)	A tree's diameter at 137cm height above ground. For trees on sloping ground, measured on the up-slope side of the tree.
Expected C-Sink curve	An expected C-Sink curve is a predictive tool that illustrates the anticipated amount of carbon to be stored in a natural carbon sink over a forthcoming ten-year period. These curves are generated by C-Sink Managers, often relying on

	historical growth patterns observed in reference areas. After adjusting for a safety margin, the curve is then subjected to verification by the designated certification body. While these certified curves can be valued for pre-purchase agreements, they are not suitable for annual global cooling assessments or compensation greenhouse gas emissions.
Forest	Contiguous area spanning ≥0.5 hectares dominated by trees ≥ 5 meters presenting a canopy coverage of ≥30 percent. The forest definition does not include land that is under agricultural or urban land use. The forest definition employed is adapted from the Food and Agriculture Organisation of the United Nations (FAO, 2020), though using an increased minimal canopy coverage. Any emergent vegetation below the stipulated thresholds is considered bushland eligible for conversion.
Global Cooling Service (GCS)	A Global Cooling Service represents both the tangible climate mitigation impact and the financial commodity derived from dynamic C-Sinks. Unlike a CO2 offset, which follows the 100%, 1000 year principle, ensuring a comprehensive annulment of a distinct emission, a GCS offers compensation for the global warming caused by a specific emission over a defined period of time, usually for one year. These services are quantified using the metric of "t aCO_2" (pronounced "ton annually stored CO_2 equivalent" or "t CO_2 equivalent per annum"). As an illustration, if a forest retains 100t CO_2e and is maintained for a decade, it can neutralize the global warming effects of a 100t CO2 emission over that 10-year span. As such, it can be marketed as 100 t aCO2 annually or 10 x 100 = 1.000 t aCO2e over 10 years.
Management unit	A management unit is a cohesive or closely associated tract of land that represents either the entire project area or a portion of it. Each management unit is limited to a maximum size of 50 hectares. For larger expanses, the area should be subdivided into multiple management units. It's essential for each management unit to be accurately mapped, with a georeferenced polygon detailing its boundaries readily available for certification purposes.
Project area	The project area refers to the designated space where a C-Sink Manager initiates and oversees tree planting activities. A single project area may encompass multiple, georeferenced management units.
Single Tree Tracking (also referred to as Single Tree Monitoring)	A C-accounting approach referring to evidence based dMRV of forests, based on a tracking of each individual tree, instead of random point measurements and extrapolation.
t aCO_2e	This unit measures global cooling services, often pronounced as "ton annually stored CO_2 equivalent A value of 1 t aCO2e

	signifies the physical containment of carbon, equivalent to the sequestration of 1 t of CO2, for a duration of one year outside the atmosphere.
Time of carbon capture	The net cooling impact resulting from carbon dioxide removal (CDR), or a negative emission, is intrinsically tied to time. Given that a negative emission induces a CO2 reflux (refer to Feedback Transmission), its cooling effect tends to wane over time. For this reason, when addressing the global warming effects precipitated by atmospheric CO2, it's crucial to factor in the timing of the carbon capture. Within biomass-based C-Sinks, this carbon capture is evaluated and depicted on an annual basis.
Tree	A woody perennial with a single main stem, or in the case of coppice with several stems, having a definite crown. This Includes bamboos, palms, and other woody plants meeting the above criteria (FAO, 2020).

Abbreviations

AGB	Above ground biomass
BGB	Below ground biomass
C	Carbon
dMRV	Digital monitoring, reporting and verification
FAO	Food and Agriculture Organisation of the United Nations.
FPIC	Free, Prior and Informed Consent
IUCN	International Union for Conservation of Nature
PDDs	Project Design Documnets
TTB	Total tree biomass
t aCO_2e	Ton of annually stored carbon dioxide equivalent
t CO_2e	Ton of carbon dioxide equivalent

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Annex 1: Accredited dMRV Approaches for Carbon Accounting

A1. The single tree tracking approach

The Global Tree C-Sink allows digital *single-tree tracking as a dMRV approach* for every certified project. An updated list of all technologies endorsed for this specific method is readily accessible online.

Single-tree tracking not only facilitates an empirical data-based evaluation of biomass-bound carbon stocks but also provides an unparalleled advantage in carbon stock tracking. It offers a high spatial resolution combined with a high temporal frequency, such as annual measurements. Using this approach, the computation of a C-Sink typically follows the methodology outlined in Figure 1 below.

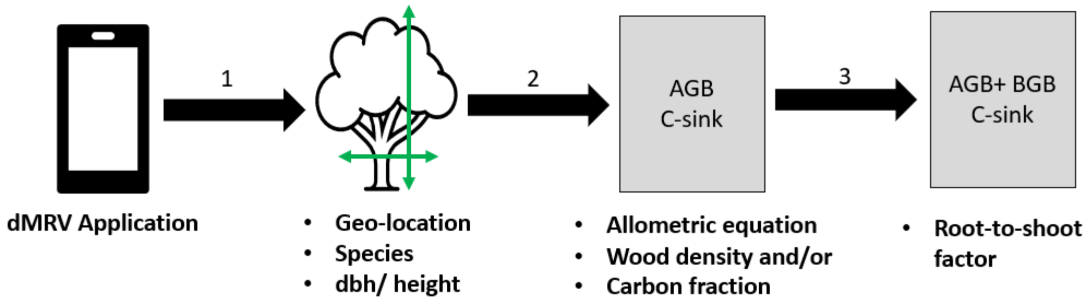

Figure A1*: Carbon sink calculation using dMRV applications for single-tree tracking. Step 1: An accredited dMRV application is utilized to monitor a single tree and calculate its current carbon sink. The dMRV application determines the trees' geolocation, species, and morphological parameters such as diameter at breast height and/or tree height. Step 2: The dMRV application employs the recorded morphological parameters in an allometric equation specific to the identified species and climate zone of the geolocation. The allometric equation calculates the trees' above-ground biomass in mass or volume. A further multiplication with the species-specific wood density (d) and/or carbon fraction (c) yields the C-Sink of the above-ground biomass. Some equations already calculate the trees' total biomass including below-ground biomass, these formulas are also permitted. In such cases, step 3 is omitted. Step 3: The calculated above-ground biomass is multiplied by a species-specific root-to-shoot factor (r), calculating the carbon sink of the total biomass (above-ground & below-ground biomass). Lastly, the total C-Sink can be translated into CO2e using a conversion factor of 44/12.*

Single-tree tracking approaches hinge on allometric equations. These equations are mathematical formulations derived from a regression analysis between tree morphology (the independent variable) and its biomass (the dependent variable). The outcomes of an allometric equation, that is, the tree biomass as the dependent variable, can be represented in either volume or mass. Such equations may utilize the tree's diameter at breast height (DBH) and/or its height as input parameters. Importantly, the units for DBH and height—whether in cm or m—should adhere to the original publication's specifications for the allometric equation in use. The resultant output of this equation can either be Above-Ground Biomass (AGB) or the Total Tree Biomass (TTB), which includes root biomass. For further standardized computations, as delineated in Table1 below, any output should be converted to t biomass or m^3 biomass as required.

Table A1: Overview of C-Sink calculations based on output from allometric equations

	Allometric equation calculating the AGB	Allometric equation calculating the TTB
Unit of equation output		
t biomass dry weight	$AGB * r * c * \frac{44}{12}$	$TTB * c * \frac{44}{12}$
m^3 biomass	$AGB * r * d * c * \frac{44}{12}$	$TTB * d * c * \frac{44}{12}$

AGB = Above ground biomass in m^3 or t calculated using an allometric equation.
TTB = Total tree biomass in m^3 or t calculated using an allometric equation.
r = Root to shoot factor (factor > 0) resolution: One decimal
d = Wood density in t m^3 (factor > 0) resolution: Two decimals
c = Carbon fraction (factor > 0 and <1) resolution: One decimal
44/12 = Factor converting t C in t CO_2e

Generally, the single-tree tracking approach is technology open, not specifying how single-tree tracking based dMRV must be realized, yet it defines criteria that need to be met by the dMRV application facilitating data collection and C-Sink calculation as per the general formulas outlined above. Companies, NGOs, or other entities can apply at Carbon Standards International for the accreditation of their single tree tracking technology to be employed under the Global Tree C-Sink.

A1.1 Operating Principles

Emerging dMRV tools enable the cost-effective monitoring of individual trees, even in spatially large projects. Single-tree tracking approaches under the Global Tree C-Sink require tracking of each single tree established by the project in the project area. Only C-Sinks from empirical measurements can be certified. The sampling and extrapolation from sampling plots or reference areas are not permitted.

Single-tree tracking is based on digital applications (smartphones, drones, satellites, etc.) that:

1. Automatically or manually localize an individual tree and record its GPS coordinates (usually based on georeferenced smartphone photographs)[14].
2. Automatically or manually[15] identify the tree species.
3. Automatically assess relevant morphological data of each single tree (diameter and/or height).
4. Automatically employ the assessed morphological data in an allometric equation, specific to the tree's geolocation (climate zone) and botanic species to calculate the tree volume/mass.
5. Automatically calculate the tree's AGB (or TTB) and consecutively the C-Sink based on volume/mass and species-specific wood density and wood carbon content as stored in an associated database.
6. Automatically calculate the TTB including the below-ground biomass (BGB) using species and climate zone-specific root-to-shoot factors (only applicable if allometric equation calculates only AGB).
7. Automatically enter the tree and the calculated C-Sink time- and georeferenced data into a project database linked to the correct C-Sink unit ID. The C-Sink Manager must retain the single tree data for at least 10 years.
8. Once per year, the aggregated C-Sink values for each C-Sink unit must be reported through an API Interface to the Global C-Sink Registry. This data transfer also includes C-Sink type, geolocation, and time-stamp of measurement.

Tree identification, including their species, can be either manually entered by individuals into a digital application or automatically determined using artificial intelligence. Specifically, this involves sophisticated algorithms designed for supervised classification. Beyond identification, all subsequent steps — assessing tree morphology and calculating its C-Sink — are fully automated. This minimizes potential human errors. Digital documentation, calculation, data storage, and transmission are crucial components of this process.

For areas that are remote or situated in hilly terrains where traditional network reception may be unreliable, alternative solutions such as Starlink, Kuiper, or IRIS2 can be utilized. Another option is to store data locally and delay its transmission. Similarly, in these regions, if there's difficulty

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[14] **Automatically:** Trees are located using supervised classification algorithms, which interpret data sources such as drone imagery. **Manually:** Individuals in the field physically locate and record trees using a dMRV application. In either approach, GPS coordinates must be automatically assigned to each tree.

[15] Automatically = automatic classification by supervised algorithms interpreting, e.g., tree bark pattern. Manually = manual input of tree species (or selection form list) in dMRV application interface.

accessing GPS, Glonass, Baidou, or IRNESS signals, a rover or a reference antenna positioned at a known location can be employed.

A1.2 Required Functionalities.

A1.2.1 Geolocation

The geolocation of an individual tree must be captured with an accuracy of less than 10 meters, adhering to the World Geodetic System (WGS1984). For improved accuracy, Galileo is recommended over GPS. All trees must be located within the polygon that defines the C-Sink unit. This polygon, outlining the project management unit or C-Sink unit should be demarcated with an accuracy of less than 5 meters. In dense forest areas, achieving this precision might necessitate the use of internal GPS systems or reference antennas[16].

Individual trees must be trackable and re-identifiable in the field. This can be achieved through various means:

- Achieving high GPS accuracies, for instance, by using a rover.
- Combining tree mapping with pattern recognition algorithms.
- Implementing tree labeling methods such as paint, lables, QR codes, RFID, NFC, AirTag, etc.

From the fifth year following the initial tree planting in any project, it's imperative that each tree can be tracked and re-identified. However, for the initial four years, recording (or counting) all trees as stipulated by the dMRV application suffices, without the specific need for single-tree tracking.

It's crucial to note that any trees recorded outside the designated polygon marking the boundaries of the project area or its sub-management unit will not be eligible for certification.

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[16] Used in, e.g., CTFS global forest plots: http://ctfs.si.edu/ctfsweb/index.php/auth/login

A1.2.2 Allometric Equations

Conditions for the accreditation and ranking of allometric formulas.

Allometric equations must be sourced from scientific, peer-reviewed literature. Any relevant literature should be submitted to Carbon Standards for verification. If the equation is taken from secondary literature or a database, it's essential to cross-reference with the original publication and make corrections if necessary.

Should there be a need to create new allometric formulas, they should strictly adhere to guidelines provided in the "Manual for building tree volume and biomass allometric equations: From field measurement to prediction" (accessible at [http://www.globallometree.org/]) or any other manual approved by Carbon Standards. It's essential that all primary data used in constructing an allometric equation undergoes a thorough plausibility check.

Furthermore, the allometric equation must specifically relate to a tree species, identified both by its genus and species epithet.

Additionally, the equation must have a defined range of validity for its independent variable, detailing the minimum and maximum values for DBH or height. These boundaries are determined based on the minimal and maximal DBH or hight found in the empirical dataset from which the equation is derived.

- **If a tree with DBH < the minimum valid DBH is to be recorded (e.g., recording newly planted seedlings), the allometric equation cannot be employed. In such case a dMRV application shall only record the small tree (picture for tree evidence, species, and GPS), but shall not calculate the C-sink based as per the allometric equation. Instead, a conservative default value of 43 g CO2[17] per seedling is assigned.**
- **If a tree with DBH > the maximum valid DBH is recorded, the DBH must be automatically corrected to the maximum valid DBH before further calculation of the C-Sink**

It's of utmost importance that the dMRV application strictly adheres to these specified ranges of validity.

The following table distinguishes three quality levels of allometric formula precision:

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[17] Corresponding to the C-sink of a generic dummy seedling of 50 cm hight,1 cm diameter, a wood density of 0.6 and a carbon content of 50%.

Table A2: Quality levels of allometric formula precision.

	🌳	🌳🌳	🌳🌳🌳
Geographic/ climatic calibration range.	The allometric equation is generated as per paired samples from the same climate zone[18] as the project location.	The allometric equation is generated as per paired samples from the same county as the project location.	The allometric equation is generated as per paired samples from the project location.
Training Dataset	Comprises ≥ 10 paired samples. The independent variable follows a normal distribution or is systematically covering a range.	Comprises ≥ 15 paired samples. The independent variable follows a normal distribution or is systematically covering a range.	Comprises ≥ 20 paired samples. The independent variable follows a normal distribution or is systematically covering a range.
Regression coefficient (or equivalent measure of statistical error)	≥0.90	≥0.90	≥0.95

A1.1.3 Training of Supervised Classification Algorithms

If algorithms are used for automatic tree identification, as opposed to manual classification by qualified operators, they must be rigorously trained and verified.

Machine learning that facilitates supervised classification, specifically to discern tree species from features like bark patterns or canopy reflectance curves (spectroscopy), requires robust validation. This validation should be anchored against field data for each species, with a minimum of n=100 replicates, and must achieve an accuracy exceeding 90% for correct species determination. This is paramount even in diverse forest compositions.

For greater flexibility and accuracy, it's permissible to employ a hybrid approach. This would entail automatic classification for more prevalent species combined with manual classification

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[18] Differentiating between main climate zones according, e.g., to the Köppen-Geiger, FAO, or WWF classification system.

for those that are rarer, especially in instances where there aren't enough samples to effectively train the algorithm.

A1.1.4 Validation of Tree Morphology Measurements

Machine learning algorithms used to compute morphological tree parameters, such as DBH and/or height, must be cross-validated against field data. For each species, this validation should involve no fewer than n=100 replicates, and the accuracy should fall within a range of -10% to +5% when compared to manually measured tree diameters or heights. When reporting results, DBH should be presented in cm with one decimal point, and height should be expressed in meters with two decimal points where relevant.

A1.1.5 Wood Density, Wood Carbon Content, and Root-to-Shoot Factor

Just like the allometric equations, values for wood density, wood carbon content, and root-to-shoot ratios need to be tailored to the species and climate zone of the project context. These values should be derived from peer-reviewed scientific literature or from publicly accessible and well-referenced official databases. If neither is available, using the IPCC standard values is acceptable.

Additionally, as an alternative, a C-Sink Manager has the option to engage a Carbon Standards -accredited laboratory[19] to carry out analyses of wood densities and carbon contents. To ensure reliability, species-specific wood densities and carbon contents should be determined based on the average values from a minimum of 5 sampled trees per species and climate zone.

A1.1.6 Root Biomass

Below-ground biomass (BGB) carbon can be included in accounting and certification processes if monitoring systems utilize an allometric equation that accounts for total biomass. Alternatively, a species and climate zone-specific factor derived from scientific, peer-reviewed literature can be used to estimate the root-to-shoot ratio[20]. New root-to-shoot ratios can be derived from empirical measurements involving a minimum of five sampled trees for each species and climate

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[19] Laboratories can contact Carbon Standards for further information on laboratory accreditation. A list of accredited laboratories will be provided online.

[20] IPCC values must be adequately referenced. The most case specific IPCC values must be used, i.e., don’t use a global mean if there is a regional or species specific factor available.

zone. If these methods are not feasible, relying on the IPCC standard values for root-to-shoot ratios is acceptable.

It's important to note that when a tree is cut down, its BGB carbon count is reset to zero. This is due to the current limitations in accurately tracking the decay of BGB over time.

A1.1.7 Documentation of Tree Harvesting

Any application designed for single tree tracking must incorporate a feature to document harvesting operations, ensuring accurate recording of the number of trees and associated carbon being removed[21]. Before felling a tree, operators use this feature to register/scan the tree.

The processes for tree registration, identification, and C-Sink calculations are consistent with those previously described. Once this function is used, the documented trees are excluded from the project's registry. Additionally, the total carbon value associated with these trees is subtracted from the value of the relevant C-Sink unit.

This feature plays a pivotal role in:

(a) Monitoring the carbon that has been removed (or remains) within a management unit (refer to principle 7 in chapter 4 “Sustainable Management”

(b) Reporting harvesting operations, which involves noting any reduction in a C-Sink unit's value to the Global C-Sink Registry promptly (within a maximum of one month post-harvest), and

(c) Setting the base for tracking biomass bound carbon to its down-stream C-Sink, such as in certified biochar or buildings. (refere to chapter 13"Downstream C-Sinks".

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[21] Given that regulatory C monitoring can occur at 5-year intervals, a distinct documentation process for harvesting operations is essential. Without this separate recording, trees that have been harvested might persist as "ghost trees" in the registry for up to five years, inaccurately reflecting cooling potentials that no longer exist.

Box A1

Generic examples for single tree tracking dMRV approaches.

Smartphone-based single tree tracking

A company managing a mixed afforestation project in Asia has introduced a smartphone-based application for individual tree tracking. When using this dMRV app, the field operator captures a photo of the tree trunk at breast height. During this process, the operator places a standardized reference plastic card against the tree trunk. The app, by comparing the relative size of the reference card in the foreground to the tree trunk in the background, automatically deduces the tree's diameter. Additionally, the tree's bark pattern aids the app in identifying the specific tree species.

Subsequently, the application employs the deduced tree diameter in a species-specific allometric equation to estimate the C-Sink. This computed C-Sink, paired with the identified species, is then linked with the tree's geolocation and a timestamp marking the moment of measurement. These recorded metrics are saved within a project-specific database which, in turn, connects to the Global Carbon Registry.

Drone-based single tree tracking

An enterprise has pioneered a dMRV system that harnesses a supervised classification algorithm, interpreting data from both multi-spectral imagery and LiDAR (Laser Imaging, Detection, and Ranging). This information is gathered annually by drones, which are deployed to map and consistently monitor the project's expanse.

Using LiDAR technology, the drone scans the project area's canopy, subsequently creating a detailed digital elevation model (DEM) of the terrain. Within this DEM, every local maximum (or peak) signifies a tree's crown. By referencing the position of the crown in this georeferenced dataset, the precise location of each individual tree can be ascertained and recorded. Moreover, by juxtaposing the height of these local maxima against a known ground reference point, the system can effectively compute the height of every individual tree.

The digital elevation model is synchronized with a multispectral image that encompasses near-infrared bands, captured by a different drone. This sophisticated classification algorithm can discern the spectral reflectance pattern characteristic of each tree crown, enabling it to correctly identify and assign a tree species to every distinct local maximum.

Following this, the deduced height of the identified tree is utilized within a species-specific allometric equation. This equation calculates the tree's C-Sink, and this computed value, in conjunction with the measurement date and precise geolocation, is securely stored in the project database.

Annex 2: Reference Values Carbon Stock in Naturally Regenerated Forests

IPCC Good Practice Guidance for LULUCF (IPCC 2003)

TABLE 3A.1.2
ABOVEGROUND BIOMASS STOCK IN NATURALLY REGENERATED FORESTS BY BROAD CATEGORY (tonnes dry matter/ha)

(To be used for Bw in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in Cropland section and for $L_{conversion}$ in Equation 3.4.13. in Grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3)

Tropical Forests [1]

	Wet	Moist with Short Dry Season	Moist with Long Dry Season	Dry	Montane Moist	Montane Dry
Africa	310 (131 - 513)	260 (159 – 433)	123 (120 - 130)	72 (16 - 195)	191	40
Asia & Oceania:						
Continental	275 (123 - 683)	182 (10 – 562)	127 (100 - 155)	60	222 (81 - 310)	50
Insular	348 (280 - 520)	290	160	70	362 (330 - 505)	50
America	347 (118 - 860)	217 (212 - 278)	212 (202- 406)	78 (45 - 90)	234 (48 - 348)	60

Temperate Forests

Age Class	Coniferous	Broadleaf	Mixed Broadleaf-Coniferous
Eurasia & Oceania			
≤20 years	100 (17 - 183)	17	40
>20 years	134 (20 - 600)	122 (18 -320)	128 (20-330)
America			
≤20 years	52 (17-106)	58 (7-126)	49 (19-89)
>20 years	126 (41-275)	132 (53-205)	140 (68-218)

Boreal Forests

Age Class	Mixed Broadleaf-Coniferous	Coniferous	Forest-Tundra
Eurasia			
≤20years	12	10	4
>20years	50	60 (12.3-131)	20 (21- 81)
America			
≤20 years	15	7	3
>20 years	40	46	15

Note: Data are given in mean value and as range of possible values (in parentheses).

[1] The definition of forest types and examples by region are illustrated in Box 2 and Tables 5-1, p 5.7-5.8 of the *IPCC Guidelines* (1996).

TABLE 3A.1.3

ABOVEGROUND BIOMASS STOCK IN PLANTATION FORESTS BY BROAD CATEGORY (tonnes dry matter/ha)

(To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in equation in Equation 3.3.8 in Cropland section and for $L_{conversion}$ in Equation 3.4.13. in Grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3)

Tropical and sub-tropical Forests

	Age Class	Wet	Moist with Short Dry Season	Moist with Long Dry Season	Dry	Montane Moist	Montane Dry
		R > 2000	2000>R>1000		R<1000	R>1000	R<1000
Africa							
Broadleaf spp	≤20 years	100	80	30	20	100	40
	>20 years	300	150	70	20	150	60
Pinus sp	≤20 years	60	40	20	15	40	10
	>20 years	200	120	60	20	100	30
Asia:							
Broadleaf	All	220	180	90	40	150	40
other species	All	130	100	60	30	80	25
America							
Pinus	All	300	270	110	60	170	60
Eucalyptus	All	200	140	110	60	120	30
Tectona	All	170	120	90	50	130	30
other broadleaved	All	150	100	60	30	80	30

Temperate Forests

	Age class	Pine	Other coniferous	Broadleaf
Eurasia				
Maritime	≤20 years	40	40	30
	>20 years	150	250	200
Continental	≤20 years	25	30	15
	>20 years	150	200	200
Mediterranean & steppe	≤20 years	17	20	10
	>20 years	100	120	80
S. America	All	100	120	90
N America	All	175 (50–275)	300	–

Boreal Forests

	Age class	Pine	Other coniferous	Broadleaf
Eurasia	≤20 years	5	5	5
	>20 years	40	40	25
N. America	All	50	40	25

TABLE 3A.1.4
AVERAGE GROWING STOCK VOLUME (1) AND ABOVEGROUND BIOMASS CONTENT (2) (DRY MATTER) IN FOREST IN 2000. (SOURCE FRA 2000)

(1) To be used for V in Equation 3.2.3.

(2) To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in cropland section and for $L_{conversion}$ in Equation 3.4.13. in grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3.

a. AFRICA

Country	Volume (aboveground) m³ / ha	Biomass (aboveground) t / ha	Infor-mation Source
Algeria	44	75	NI
Angola	39	54	NI
Benin	140	195	PI
Botswana	45	63	NI
Burkina Faso	10	16	NI
Burundi	110	187	ES
Cameroon	135	131	PI
Cape Verde	83	127	ES
Central African Republic	85	113	PI/EX
Chad	11	16	ES
Comoros	60	65	ES
Congo	132	213	EX
Côte d'Ivoire	133	130	PI
Dem. Rep. of the Congo	133	225	NI
Djibouti	21	46	ES
Egypt	108	106	ES
Equatorial Guinea	93	158	PI
Eritrea	23	32	NI
Ethiopia	56	79	PI
Gabon	128	137	ES
Gambia	13	22	NI
Ghana	49	88	ES
Guinea	117	114	PI
Guinea-Bissau	19	20	NI
Kenya	35	48	ES
Lesotho	34	34	ES
Liberia	201	196	ES
Libyan Arab Jamahiriya	14	20	ES

Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)

TABLE 3A.1.4 (CONTINUED)
AVERAGE GROWING STOCK VOLUME (1) AND ABOVEGROUND BIOMASS CONTENT (2) (DRY MATTER) IN FOREST IN 2000. (SOURCE FRA 2000)

(1) To be used for V in Equation 3.2.3.

(2) To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in cropland section and for $L_{conversion}$ in Equation 3.4.13. in grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3.

a. AFRICA (Continued)

Country	Volume (aboveground) m³ / ha	Biomass (aboveground) t / ha	Infor-mation Source
Madagascar	114	194	NI
Malawi	103	143	NI
Mali	22	31	PI
Mauritania	4	6	ES
Mauritius	88	95	ES
Morocco	27	41	NI
Mozambique	25	55	NI
Namibia	7	12	PI
Niger	3	4	PI
Nigeria	82	184	ES
Réunion	115	160	ES
Rwanda	110	187	ES
Saint Helena			
Sao Tome and Principe	108	116	NI
Senegal	31	30	NI
Seychelles	29	49	ES
Sierra Leone	143	139	ES
Somalia	18	26	ES
South Africa	49	81	EX
Sudan	9	12	ES
Swaziland	39	115	NI
Togo	92	155	PI
Tunisia	18	27	NI
Uganda	133	163	NI
United Republic of Tanzania	43	60	NI
Western Sahara	18	59	NI
Zambia	43	104	ES
Zimbabwe	40	56	NI

Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)

TABLE 3A.1.4
AVERAGE GROWING STOCK VOLUME (1) AND ABOVEGROUND BIOMASS CONTENT (2) (DRY MATTER) IN FOREST IN 2000. (SOURCE FRA 2000)

(1) To be used for V in Equation 3.2.3.

(2) To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in cropland section and for $L_{conversion}$ in Equation 3.4.13. in grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3.

b. ASIA

Country	**Volume (aboveground)**	**Biomass (aboveground)**	**Infor-mation**
	m³ / ha	**t / ha**	**Source**
Afghanistan	22	27	FAO
Armenia	128	66	FAO
Azerbaijan	136	105	FAO
Bahrain	14	14	FAO
Bangladesh	23	39	FAO
Bhutan	163	178	FAO
Brunei Darussalam	119	205	FAO
Cambodia	40	69	FAO
China	52	61	NI
Cyprus	43	21	FAO
Dem People's Rep. of Korea	41	25	ES
East Timor	79	136	FAO
Gaza Strip			
Georgia	145	97	FAO
India	43	73	NI
Indonesia	79	136	FAO
Iran, Islamic Rep.	86	149	FAO
Iraq	29	28	FAO
Israel	49	-	FAO
Japan	145	88	FAO
Jordan	38	37	FAO
Kazakhstan	35	18	FAO
Kuwait	21	21	FAO
Kyrgyzstan	32	-	FAO
Lao People's Dem. Rep	29	31	NI
Lebanon	23	22	FAO
Malaysia	119	205	ES
Maldives	-	-	-
Mongolia	128	80	NI
Myanmar	33	57	NI
Nepal	100	109	PI
Oman	17	17	FAO
Pakistan	22	27	FAO
Philippines	66	114	NI
Qatar	13	12	FAO
Republic of Korea	58	36	NI
Saudi Arabia	12	12	FAO
Singapore	119	205	FAO
Sri Lanka	34	59	FAO
Syrian Arab Rep.	29	28	FAO
Tajikistan	14	10	FAO
Thailand	17	29	NI
Turkey	136	74	FAO
Turkmenistan	4	3	FAO
United Arab Emirates	-	-	-
Uzbekistan	6		FAO
Viet Nam	38	66	ES
West Bank	-	-	-
Yemen	14	19	FAO

Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)

TABLE 3A.1.4 (CONTINUED)
AVERAGE GROWING STOCK VOLUME (1) AND ABOVEGROUND BIOMASS CONTENT (2) (DRY MATTER) IN FOREST IN 2000. (SOURCE FRA 2000)

(1) To be used for V in Equation 3.2.3.

(2) To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in cropland section and for $L_{conversion}$ in Equation 3.4.13. in grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3.

c. OCEANIA

Country	**Volume (aboveground) m³ / ha**	**Biomass (aboveground) t / ha**	**Infor-mation Source**
American Samoa			
Australia	55	57	FAO
Cook Islands	-	-	-
Fiji	-	-	-
French Polynesia	-	-	-
Guam	-	-	-

Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)

Table 3A.1.4 (Continued)
Average growing stock volume (1) and aboveground biomass content (2) (dry matter) in forest in 2000. (source FRA 2000)

(1) To be used for V in Equation 3.2.3.

(2) To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in cropland section and for $L_{conversion}$ in Equation 3.4.13. in grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3.

c.OCEANIA (Continued)

Country	Volume (aboveground) m^3 / ha	Biomass (aboveground) t / ha	Information Source
Kiribati	-	-	-
Marshall Islands	-	-	-
Micronesia	-	-	-
Nauru	-	-	-
New Caledonia	-	-	-
New Zealand	321	217	FAO
Niue	-	-	-
Northern Mariana Isl.	-	-	-
Palau	-	-	-
Papua New Guinea	34	58	NI
Samoa	-	-	-
Solomon Islands	-	-	-
Tonga	-	-	-
Vanuatu	-	-	-

Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)

Table 3A.1.4 (Continued)
Average growing stock volume (1) and aboveground biomass content (2) (dry matter) in forest in 2000. (source FRA 2000)

(1) To be used for V in Equation 3.2.3.

(2) To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in cropland section and for $L_{conversion}$ in Equation 3.4.13. in grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3.

d. EUROPE

Country	Volume (aboveground) m^3 / ha	Biomass (aboveground) t / ha	Information Source
Albania	81	58	FAO
Andorra	0	0	FAO
Austria	286	250	FAO
Belarus	153	80	FAO
Belgium & Luxembourg	218	101	FAO
Bosnia & Herzegovina	110	-	FAO
Bulgaria	130	76	FAO

Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)

Table 3A.1.4 (Continued)
Average growing stock volume (1) and aboveground biomass content (2) (dry matter) in forest in 2000. (source FRA 2000)

(1) To be used for V in Equation 3.2.3.

(2) To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in cropland section and for $L_{conversion}$ in Equation 3.4.13. in grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3.

d. EUROPE (Continued)

Country	Volume (aboveground) m^3 / ha	Biomass (aboveground) t / ha	Information Source
Croatia	201	107	FAO
Czech Republic	260	125	FAO
Denmark	124	58	FAO
Estonia	156	85	FAO
Finland	89	50	NI
France	191	92	FAO
Germany	268	134	FAO
Greece	45	25	FAO
Hungary	174	112	FAO
Iceland	27	17	FAO
Ireland	74	25	FAO
Italy	145	74	FAO
Latvia	174	93	FAO
Liechtenstein	254	119	FAO
Lithuania	183	99	FAO
Malta	232		FAO
Netherlands	160	107	FAO
Norway	89	49	FAO
Poland	213	94	FAO
Portugal	82	33	FAO
Republic of Moldova	128	64	FAO
Romania	213	124	FAO
Russian Federation	105	56	FAO
San Marino	0	0	FAO
Slovakia	253	142	FAO
Slovenia	283	178	FAO
Spain	44	24	FAO
Sweden	107	63	NI
Switzerland	337	165	FAO
The FYR of Macedonia	70	-	FAO
Ukraine	179	-	FAO
United Kingdom	128	76	FAO
Yugoslavia	111	23	FAO

Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)

TABLE 3A.1.4 (CONTINUED)
AVERAGE GROWING STOCK VOLUME (1) AND ABOVEGROUND BIOMASS CONTENT (2) (DRY MATTER) IN FOREST IN 2000. (SOURCE FRA 2000)

(1) To be used for V in Equation 3.2.3.

(2) To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in cropland section and for $L_{conversion}$ in Equation 3.4.13. in grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3.

e. NORTH AND CENTRAL AMERICA

Country	Volume (aboveground) m^3 / ha	Biomass (aboveground) t / ha	Information Source
Antigua and Barbuda	116	210	ES
Bahamas	-	-	-
Barbados	-	-	-
Belize	202	211	ES
Bermuda	-	-	-
British Virgin Islands	-	-	-
Canada	120	83	FAO
Cayman Islands	-	-	-
Costa Rica	211	220	ES
Cuba	71	114	NI
Dominica	91	166	ES
Dominican Republic	29	53	ES
El Salvador	223	202	FAO
Greenland	-	-	-
Grenada	83	150	PI
Guadeloupe	-	-	-
Guatemala	355	371	ES
Haiti	28	101	ES
Honduras	58	105	ES
Jamaica	82	171	ES
Martinique	5	5	ES
Mexico	52	54	NI
Montserrat	-	-	-
Netherlands Antilles	-	-	-
Nicaragua	154	161	ES
Panama	308	322	ES
Puerto Rico	-	-	-
Saint Kitts and Nevis	-	-	-
Saint Lucia	190	198	ES
Saint Pierre & Miquelon	-	-	-

Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)

TABLE 3A.1.4 (CONTINUED)
AVERAGE GROWING STOCK VOLUME (1) AND ABOVEGROUND BIOMASS CONTENT (2) (DRY MATTER) IN FOREST IN 2000. (SOURCE FRA 2000)

(1) To be used for V in Equation 3.2.3.

(2) To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in cropland section and for $L_{conversion}$ in Equation 3.4.13. in grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3.

e. NORTH AND CENTRAL AMERICA (Continued)

Country	Volume (aboveground) m^3 / ha	Biomass (aboveground) t / ha	Information Source
Saint Vincent and Grenadines	166	173	NI
Trinidad and Tobago	71	129	ES
United States	136	108	FAO
US Virgin Islands	-	-	-

TABLE 3A.1.4 (CONTINUED)
AVERAGE GROWING STOCK VOLUME (1) AND ABOVEGROUND BIOMASS CONTENT (2) (DRY MATTER) IN FOREST IN 2000. (SOURCE FRA 2000)

(1) To be used for V in Equation 3.2.3.

(2) To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in cropland section and for $L_{conversion}$ in Equation 3.4.13. in grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3.

f. SOUTH AMERICA

Country	Volume (aboveground) m^3 / ha	Biomass (aboveground) t / ha	Information Source
Argentina	25	68	ES
Bolivia	114	183	PI
Brazil	131	209	ES
Chile	160	268	ES
Colombia	108	196	NI
Ecuador	121	151	ES
Falkland Islands	-	-	-
French Guiana	145	253	ES
Guyana	145	253	ES
Paraguay	34	59	ES
Peru	158	245	NI
Suriname	145	253	ES
Uruguay	-	-	-
Venezuela	134	233	ES

Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)