METHODOLOGICAL DOCUMENT
AFOLU SECTOR

BCR0007 Conservation and restoration of natural continental wetlands

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Credits

This methodological document was developed by Ángela Duque and the technical team of "*Proyecto CO_2 Humedales*" of Fundación Natura, within the framework of agreement No. 3044288 signed between Ecopetrol and Fundación Natura.

The "*Proyecto CO_2 Humedales*" aims to join efforts for the conservation and restoration of tropical forest ecosystems at the national level and of natural continental wetlands in the middle and lower Magdalena, as well as the formulation and implementation of actions for the mitigation of GHG emissions generated by avoiding the degradation of these ecosystems.

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1 Introduction

Continental natural wetlands are considered strategic ecosystems worldwide because of their importance in climate regulation. According to the Ramsar Convention, wetlands cover only 9% of the planet's land surface, but it is estimated that they store 35% of terrestrial carbon[1], thanks to the high productivity of plants and the low decomposition of organic matter that occurs in their flooded soils. In addition, wetlands are indispensable for the innumerable ecosystem services they provide to humanity, ranging from the provision of fresh water, food and building materials, and biodiversity, to flood control, groundwater recharge, and climate change mitigation[2].

However, the area and quality of wetlands have been decreasing in most regions of the world and are currently disappearing three times faster than forests[3] consequently, among others, of the effects of climate change and variations in consumption patterns that drive changes in land use, resulting in accelerated land use change[4].

Consequently, within the framework of conservation and restoration measures for Continental natural wetlands, this methodology establishes guidelines for the development of activities related to the management of resources in these strategic ecosystems, to face the challenges of climate change and offer sustainable sources of income for the local communities.

On the other hand, the development and implementation of actions aimed at the conservation and restoration of natural Continental wetlands favors climate change mitigation and the permanence of the biodiversity associated with these ecosystems.

This document provides GHG project holders with best practices related to procedures, models, parameters and data for quantifying GHG emission reductions and/or removals attributable to activities that avoid land use change and/or improve continental wetland ecosystem conditions. In this sense, this document contains the requirements for the identification of the baseline scenario, project boundaries, additionality, identification and management of leakages, estimation of uncertainty, as well as variations in carbon stocks.

[1] https://www.ramsar.org/es

[2] Ramsar, 2015. State of the World's Wetlands and their Services to People: A compilation of recent analyses. Available at: https://www.ramsar.org/sites/default/files/documents/library/strp19_4_bn7_e.pdf

[3] Convention on Biological Diversity (CBD), 2020. Statement by Elizabeth Maruma Mrema. Acting Executive Secretary, Convention on Biological Diversity on the occasion of World Wetlands Day. Available at: https://www.cbd.int/doc/speech/2020/sp-2020-01-31-wwd-en.pdf

[4] Ramsar, 2015. The State of the World's Wetlands and Their Services to People: A Compilation of Recent Analyses. Available at: https://www.ramsar.org/sites/default/files/documents/library/bn7s.pdf

2 Purpose

The purpose of this methodological document (hereinafter referred to as this Methodology) is to define the requirements for:

(a) identify the baseline of conservation and restoration projects in continental natural wetlands;

(b) demonstrate the additionality of conservation and restoration projects in continental natural wetlands;

(c) quantify the reduction of GHG emissions resulting from conservation and restoration activities in continental natural wetlands;

(d) determine and quantify leakages and implement actions related to their management;

(e) estimate the uncertainty regarding the quantification of GHG emission reductions;

(f) design the monitoring plan for project activities that prevent land-use change in the continental natural wetlands.

3 Version and validity

This document constitutes version 1.0, from June 13, 2024.

This version may be updated from time to time and intended users shall ensure that they use the most recent version of the document.

4 Scope

This document provides a methodology for quantifying greenhouse gas (GHG) emission reductions, including monitoring project activities and uncertainty, for GHG projects that avoid land-use change and propose conservation and restoration activities in continental natural wetlands.

This methodology is applicable for quantifying emissions reductions attributable to project activities that generate GHG emission reductions through conservation and restoration activities in continental natural wetlands. The methodology has no geographic restrictions and is applicable on a global scale.

The project activities may, optionally, involve biodiversity conservation actions, either through preservation, restoration and/or sustainable management and use of areas in continental natural wetlands.

This methodology can be used by GHG project holders only for certification and registration under the BCR STANDARD.

5 Applicability conditions

This Methodology is applicable under the following conditions:

(a) the areas within the project's geographical boundaries correspond to the category of continental natural wetlands[5], located in geographical zones other than the Orinoquia[6] region;

(b) the project activities prevent land-use change in continental natural wetlands;

(c) the project activities include actions to prevent the transformation of natural vegetation cover in continental natural wetlands;

(d) the project activities involve conservation actions including preservation, restoration, and/or sustainable management of continental natural wetlands;

(e) the project activities include assisted natural restoration in areas that have been transformed;

(f) the project activities determine changes in the use of nitrogen fertilizers, reducing or eliminating their application;

(g) the project activities do not generate changes in the ecosystem, nor alter natural covers (e.g., transforming areas naturally dominated by herbaceous covers into forest covers);

(h) the project activities proposed do not include the removal (total or partial) of natural vegetation covers (including forests and other natural covers different from forests);

[5] The project owner must ensure that ecosystems classified as continental natural wetlands are identified, based on the official information available in the country in which the project is developed.
[6] The term Orinoquia includes the entire Orinoquia region (present in Colombia and Venezuela). Owners of projects located in the Orinoquia shall use the BCR0004 methodology.

(i) the project activities do not lead to alteration of the water regime in the project area or hydrologically connected areas due to anthropogenic interventions (e.g., irrigation systems and/or drainage);

(j) the project activities are implemented in areas where there are no other restoration activities planned or ongoing.

This methodology is not applicable to coastal-marine humid areas, high mountains, or artificialized territories.

6 Normative References

The following references are indispensable for the application of this Methodology:

(a) The BCR STANDARD, in its most recent version;

(b) IPCC 2003, 2006, 2013, and 2019 Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, forestry and other land uses, or those that modify or update them;

(c) National legislation related to GHG projects, or those regulations that modify or update them, as applicable;

(d) The guidelines, other orientations and/or guides defined by BIOCARBON, in the scope of the projects in the AFOLU sector;

Likewise, it is essential to comply with the following ISO Standards:

a) ISO 14064-2:2019. Greenhouse gases - Specification with guidance, at the project level, for the quantification, monitoring and reporting of emission reductions or enhancement of greenhouse gas removals, or that which updates it;

b) ISO 14064-3:2019. Greenhouse gases - Part 3: Specification with guidance for validation and verification of greenhouse gas declarations, or that which updates it.

7 Terms and definitions

Activity Data

Data on the magnitude of human activities that give rise to emissions or removals occurring over a specified period.

Additionality

Is the effect of the GHG Project activity to reduce anthropogenic GHG emissions below the level that would have occurred in the absence of the GHG Project activity[7].

Those GHG reductions that the project owner demonstrates would not occur in the absence of the GHG project are considered additional, as described in section 11 of this document.

Agriculture, Forestry, and Other Land Use (AFOLU)

Sector comprising greenhouse gas emissions and/or removals attributable to project activities in the agriculture, forestry and other land use sector.

Aquatic Vegetation

Aquatic vegetation grows and develops in aquatic environments, consisting of herbaceous plants whose dynamics vary over time according to hydroclimatic seasonality (rainy and dry seasons) and space (distribution within the water basin). Thus, submerged, floating, and rooted aquatic communities can be distinguished[8].

Assisted Regeneration

Restoration activities that encourage the natural regeneration capacity of the remaining biota on the side or nearby, rather than reintroducing the biota to the site or leaving a site to regenerate on its own. Although this approach is typically applied to sites with low to intermediate degradation, even some highly degraded sites have proven suitable for assisted regeneration, provided there are adequate treatments and sufficient timeframes. Interventions include the removal of pest organisms, the reintroduction of disturbance regimes, and the implementation of resources to accelerate colonization[9].

Baseline scenario

The scenario for the GHG project that reasonably represents the sum of carbon stock changes within the project boundary that would occur in the absence of the GHG project[10].

Biomass

The amount of living matter of plant or animal origin present at a given time, in a given area that contains Carbon within its body structure. In the case of terrestrial plant material, aerial

[7] Adopted from MDL Glossary terms.
[8] Rial, A. (2003). The concept of aquatic plants in a wetland of the Venezuelan Llanos. Memoirs of the La Salle Foundation of Natural Sciences (155), 119-132.
[9] Adapted from SER, 2004; 2019, UNEP, 2019, IPBES, 2018: - Society for Ecological Restoration International Science & Policy Working Group. 2004. www.ser.org
[10] Adapted of Glossary CDM terms. Version 10.0

biomass refers to stems, branches, bark, seeds and living foliage, in addition to that found floating on bodies of water, which also includes underground root material with more 2 mm in diameter for the absorption of water and nutrients and other physiological and support functions[11].

Carbon Fraction

Tons of carbon per ton of dry biomass. According to IPCC (2006) the carbon fraction is 0.47.

Conservation of wetland ecosystems

Activities that are developed with the purpose of preserving/conserving the carbon content available in natural wetland areas.

Ecological Restoration

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. It involves intentional activities that initiate or accelerate the recovery of ecological functionality or the establishment of an ecosystem that has been degraded, damaged, or destroyed[12]. Restoration includes interventions such as: (a) ecological restoration, (b) ecological rehabilitation, and (c) ecological recovery or reclaiming.

Ecological restoration aims to restore the degraded ecosystem to a condition similar to its pre-disturbance state in terms of composition, structure, and function. Additionally, the resulting ecosystem must be self-sustaining and ensure the conservation of species, the overall ecosystem, and most of its goods and services. Ecological restoration always addresses biodiversity conservation and ecological integrity.

Ecological rehabilitation seeks to bring the degraded system back to a state similar or not dissimilar to its pre-disturbance state. It should be self-sustaining, preserve some species, and provide some ecosystem services.

Ecological recovery or reclaiming aims to restore some ecosystem services of social interest. Generally, the resulting ecosystems are not self-sustaining and do not resemble the pre-disturbance system. It relates to the process of making severely degraded lands (e.g., former mines or landfills) suitable for cultivation or achieving a suitable state for human use.

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[11] Yepes, A. P., Navarrete, D. A., Duque, A. J., Phillips, J. F., Cabrera, K. R., Álvarez, E., ... & Ordoñez, M. F. (2011). Protocol for the national and subnational estimation of biomass-carbon in Colombia. Institute of Hydrology, Meteorology, and Environmental Studies-IDEAM-. Bogotá DC, Colombia, 162

12 Adapted from SER, 2004; 2019, UNEP, 2019, IPBES, 2018: - Society for Ecological Restoration International Science & Policy Working Group. 2004. www.ser.org

Ecosystem

Dynamic complex of plant, animal and microorganism communities in their non-living environment that interact as a functional unit materialized in a territory, which is characterized by homogeneity in its biophysical and anthropic conditions[13].

Floodplain

The floodplain is the area that is periodically or seasonally inundated due to the rise in water level, whether caused by precipitation, river flooding, or other events.

GHG Emission Factor

Coefficient relating GHG activity data to GHG emission.

GHG Project (Greenhouse gases project)

Activity or activities that change the conditions of a GHG baseline and cause GHG emissions to be reduced or GHG removals to be increased[14].

Greenhouse gas reservoir (GHG pool)

A component, distinct from the atmosphere, that has the capacity to accumulate GHGs and to store and release them[14].

Note 1 to entry: The total mass of carbon contained in a GHG pool at a specific point in time can be referred to as the carbon pool of the pool.

Note 2 to entry: A GHG reservoir may transfer GHGs to another GHG reservoir.

Note 3 to entry: The collection of a GHG from a GHG source before it enters the atmosphere and the storage of the collected GHG in a GHG reservoir could be referred to as GHG capture and GHG storage.

Hydric or hydromorphic soils

Hydric or hydromorphic soils are those that are saturated with water or flooded for some periods of the year. These anaerobic (without oxygen) conditions cause physical and chemical alterations in the soil that affect its constituents, properties, formation, and evolution.

In wetlands, soils are a determining factor, since they are where the stress caused by oxygen scarcity occurs and where organic matter decomposes at a greater or lesser rate. They are

[13] In accordance with the definition contained in the Convention on Biological Diversity (1992). Available at: https://www.cbd.int/
[14] ISO 14064-3:2019(en), 3.4.1.

fundamental in the delimitation of wetland areas, as they record the history of the wetland and remain even after the wetland has been drained and the hydrophytic vegetation has disappeared.[15]

Land use change

Changes in land use that constitute loss of natural cover. That is, changes generated by anthropic activities that result in the conversion of forests or natural vegetation cover to other land uses. When the land use change is from forest cover to another type of cover, it is called deforestation[16].

Landscape Management Tools

These are elements of the landscape that constitute or enhance the habitat, increase functional connectivity, or simultaneously fulfill these functions for the benefit of native biodiversity[17].

Leakages

Potential emissions that would occur outside the project boundary from GHG mitigation activities. Leakage means the net change in anthropogenic emissions by sources of greenhouse gases (GHG) that occurs outside the project boundary, and that is measurable and attributable to the project activity.

Natural area

An area that is characterized by the conservation of its ecological functions and has not been transformed by man.

Natural continental wetland

Permanently or temporarily flooded ecosystems, typical of floodplains, subject to the hydro-climatic behavior of the basin, ranging from areas with saturated soils (to where the soils show evidence of oxidation-reduction processes): redoximorphic conditions) and hydrophytic vegetation (adapted to withstand periods of flooding), to areas with visible and deep water mirrors, where organisms (microbiota, fauna and flora) with particular adaptations to wet conditions are found and which offer ecosystem services and uses that

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[15] MITSCH W & G GOSSELINK (2007) Wetlands. Fourth edition, John Wiley & Sons Inc., New York, USA

[16] BCR0003 Quantification of GHG Emissions Reduction. Activities that prevent land use change and improve management practices for peatlands and other wetlands in high mountain ecosystems. Version 3.0.

[17] RENJIFO, L. M., ARISTIZÁBAL, S. L., LOZANO-ZAMBRANO, F. H., VARGAS, W., VARGAS, A. M., & RAMÍREZ, D. P. (2009). Design of the conservation strategy in the rural landscape (Phase II). pp. 85-119. In: Lozano-Zambrano, F. H. (ed). Management tools for the conservation of biodiversity in rural landscapes. Institute of Biological Resources Research Alexander von Humboldt and Regional Autonomous Corporation of Cundinamarca (CAR). Bogotá, D.C.

benefit the local and regional community[18].

Natural forest

A minimum area of land between 0.05 and 1.0 hectares (ha) with a canopy cover (or equivalent stocking density) exceeding 30% and with trees that can reach a minimum height of 5 meters (m). A forest may consist of dense forest formations, where trees of various heights and undergrowth cover a considerable proportion of the ground, or a clear stand. Natural forest stands and all young plantations that have not yet reached a crown density of 30% or a tree height of between 2 and 5 m, as well as areas that are normally part of the forest area but are temporarily devoid of forest population as a result of human intervention, e.g., harvesting, or natural causes, but which are expected to revert to forest, are also considered forests[19]

Natural Vegetation Covers, different than forest

This encompasses a group of vegetation covers of a natural type, resulting from natural succession, with a growth habit that is shrubby and herbaceous, developed on different substrates and altitudinal zones, with little or no anthropic intervention. According to CORINE Land Cover, this class includes other types of cover such as areas covered by primarily shrubby vegetation with an irregular canopy and the presence of shrubs, palms, vines, and low-growing vegetation.

For the application of this methodology, this definition includes natural vegetation cover present in the continental natural wetland, such as hydrophytic vegetation found from the water surface to the floodable area. This includes natural covers different from forest, such as aquatic and swamp vegetation, as well as the floodable forest itself.

Permanence

The condition resulting from project activities whereby the system established within the project boundaries is continuously extended, ensuring that the function of conserving carbon stocks is maintained over time.

Project start date

Date on which activities that will result in actual GHG emission reductions or removals begin. For GHG projects applying this methodology, the start date corresponds to the date on which the implementation of project activities begins. These may be, for example, the planting of native species in transformed areas and/or the initiation of management actions that reduce

[18] Fundación Natura, 2024. CO2 Wetlands Project. Agreement No. 3044288 (Ecopetrol and Fundación Natura).
19 Adapted of UNFCCC. Marrakesh Accords. Available at https://unfccc.int/resource/docs/cop7/13a01.pdf. The project holder shall use the definition applicable in his country.

pressure from the transformation of wetland areas with natural vegetation cover within the project boundaries.

Reference Area

These are the geographical boundaries within which historical patterns of land use change and degradation are analyzed. These patterns will be projected onto the project area to obtain values for changes in natural vegetation covers in the baseline scenario within the project area.

Revegetation

The establishment, by any means, of plants in sites (including terrestrial, freshwater, and marine areas) that may or may not involve local or native species[20].

Sediments

Sediments are materials that result when rocks undergo weathering processes (fragmentation). Some processes physically break the rock into smaller pieces without altering its composition, while others chemically decompose the rock, transforming minerals into new ones and substances easily soluble in water. Water, wind, or glacial ice often transport the products of weathering to sedimentation sites where they form relatively flat layers[21].

Unlike soils, which consist of gaseous, liquid, and solid phases, submerged sediments are composed only of solid and liquid phases[22]. On the other hand, sediments deposited on beaches and riparian zones of wetlands correspond to the parent materials of the soil, including Sand (S), Silt (Si), and Clay (Cl). The solid phase consists of both organic and mineral components. Sediments are always an intimate mixture of organic, mineral, and liquid phases, where organic remains and various organic substances constitute the organic

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[20] Gann GD, McDonald T, Walder B, Aronson J, Nelson CR, Jonson J, Hallett JG, Eisenberg C, Guariguata MR, Liu J, HuaF, Echeverría C, Gonzales E, Shaw N, Decleer K, Dixon KW (2019) International principles and standards for the practice of ecological restoration. Second edition. Restoration Ecology 27(S1): S1–S46.

[21] Edward J. Tarbuck, Frederick K. Lutgens. 2005. Earth Sciences: An Introduction to Physical Geology. Universidad Autónoma de Madrid. Available at: https://apiperiodico.jalisco.gob.mx/api/sites/periodicooficial.jalisco.gob.mx/files/ciencias-de-la-tierra_edward_j.tarbuck_y_frederick_k._lutgens.pdf

[22] Avnimelech Y, Ritvo G, Meijer L, Kochba M. "Water content, organic carbon and dry bulk density in flooded sediments." Aquacultural Engineering 2001; 25: 25-33. Available at: https://www.researchgate.net/publication/222514599_Water_content_organic_carbon_and_dry_bulk_density_in_flooded_sediments

phase, while non-volatile cations, minerals, mineraloids, and other inorganic substances make up the inorganic phase; the liquid phase is primarily water[23].

Soil

Soil is a natural body made up of solid (minerals and organic matter), liquid and gaseous materials inhabited by macro and microorganisms that carry out permanent biotic and abiotic processes; it fulfills vital ecosystemic functions and services for society and the planet[24].

Soils cover most of the earth's surface; they are indispensable and determinant for the structure and functioning of water, air and nutrient cycles; they are an essential part of biogeochemical cycles, in which there is distribution, transport, storage and transformation of materials and energy necessary for life on the planet, as well as for biodiversity. Their formation can take thousands of years as a result of physical, chemical and biological weathering and weathering associated with the interaction between climate, geomorphology, the geological material that originates them and the organisms that live in them. Soils are systems where different types of processes occur, such as gains, losses, movements and transformations that leave their mark in the form of horizons[25].

Transformation drivers

Any natural or man-made action that generates changes in ecosystems[26]. They can be direct, when there is a strong influence on ecosystem functioning (climate variability, landscape changes, nutrient injection into the soil for agricultural purposes, resource exploitation and use, and biological invasions) or indirect when their effect is not clearly visible (population growth, socio-political or economic trends, scientific advances to improve biomass production, and human behavior)[27].

Transformed area

Area that has experienced changes in its physical and biotics conditions.

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[23] Parra, L. 2005. High-resolution facial analysis of Late Holocene sediments in the Frontino Paramo (Antioquia). Doctoral Thesis. Institute of Natural Sciences. National University of Colombia. 214 pp. Available at: https://www.limnetica.com/documentos/limnetica/limnetica-28-1-p-65.pdf
24 USDA. (2006). Claves para la Taxonomía de Suelos. 10a ed. Washington D.C.: Soil Survey Staff. Departamento de Agricultura de los Estados Unidos. Servicio de Conservación de Recursos Naturales.
25 IDEAM, U.D.C.A., 2015. Protocolo para la identificación y evaluación de la degradación de suelos por erosión. IDEAM - MADS -U.D.C.A Bogotá D.C., Colombia., 170 págs. Versión 2. Publicación aprobada por el IDEAM, diciembre de 2015, Bogotá D.C., Colombia
26 Carpenter, S., Bennett, E., and Peterson, G. (2006). Scenarios for ecosystem services: An overview. Ecol. Soc. 11, art29. doi:10.5751/es-01610-110129
27 Nelson, G. C., Bennett, E., Berhe, A. A., Cassman, K., DeFries, R., Dietz, T. (2006). Anthropogenic drivers of ecosystem change: An overview. Ecol. Soc. 11 (2), 29. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/ art29/.

Wetland

According to the Ramsar Convention on the Protection of Wetlands (Article 1) "wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters" (Ramsar, 1971) [28].

Wet Soils

A wet soil is a soil that is inundated or saturated by water for all or part of the year to the extent that biota, adapted to anaerobic conditions, particularly soil microbes and rooted plants, control the quality and quantity of the net annual greenhouse gas emissions and removals.[29]

8 Project boundaries

8.1 Spatial boundaries

8.1.1 Eligible area

The project holder shall identify eligible areas for implementing ecological restoration and revegetation activities within the project boundaries. To achieve this, a multi-temporal analysis shall be conducted between the project start date (t=0) and at least five years prior to that date.

8.1.1.1 Areas Eligible for implementation of restoration activities

The project holder shall define the eligible area for implementing restoration activities, demonstrating the following:

(a) the area corresponds to transformed land covers;

(b) the areas within the geographical boundaries of the project do not correspond to the category of natural cover, neither at the start of the project activities, nor three years before the project start date.

[28] https://ramsar.org/documents?field_quick_search=2550
[29] 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Available in https://www.ipcc-nggip.iges.or.jp/public/wetlands/pdf/Wetlands_separate_files/WS_Chp1_Introduction.pdf

8.1.1.2 *Eligible area for implementation of conservation activities*

For ecological restoration activities, eligible areas are those that maintain natural cover during the analysis period. The following shall be met:

(a) Areas are classified as natural vegetation covers throughout the required multi-temporal analysis period;

(b) Land covers shall be identified according to land use and/or land cover classifications provided by the IPCC or those applicable to the country where the project activities are proposed.

Areas within the geographical boundaries of the project shall be classified as continental natural wetlands. To demonstrate that the project boundaries correspond to the category of continental natural wetland, the project holder shall have data and geographic information at a minimum scale of 1:25,000. The accuracy of the cover layer shall be equal to or greater than 80%. Additionally, field data or high-resolution images shall be used for accuracy assessment[30].

Cartographic inputs for identifying land covers/uses and the methodological process for generating information on land use changes shall be based on reliable information, using defined land use categories, for example, those by the IPCC for national Greenhouse Gas Inventories (GHG). These categories shall be consistent with applicable land use categories in the country where the GHG project is proposed.

For identifying natural vegetation covers different from forests, the GHG project holder shall use categories defined by the CORINE Land Cover methodology or those applicable in the country where the project is being developed.

8.1.2 Leakage area

Area outside the control of the GHG project holder with natural covers to which land use change activities may shift as a result of project activities. To identify this, the project holder shall conduct an analysis of the mobility of agents and determinants of land use change.

The leakage area shall be delimited based on the following criteria:

[30] Geographic data shall be managed following international standards promoted by organizations such as ISO, OGC, or the American Society for Photogrammetry and Remote Sensing.

a) it shall include all areas classified as continental natural wetlands within the mobility range of the agents identified in Section 12 (below)[31];

b) the leakage area is spatially distinct from the project area, meaning they do not overlap;

c) the leakage area excludes areas with restricted access to agents causing land use change in continental natural wetlands (drivers of transformation).

d) whether the leakage area overlaps with other GHG project areas, an analysis shall be conducted on how project activities affect transformation agents and measures for their management.

8.1.3 Reference region

The reference region corresponds to the spatial boundary within which estimates of land use changes and carbon stock changes are made in the absence of the project.

The project holder shall define the reference region considering the following guidelines:

(a) Demonstrate that the determinants of land use change (drivers of transformation) are like those presented in the project area;

(b) Demonstrate that the environmental conditions (ecosystem type, cover, altitude, precipitation, slope, soils) are like those found in the project area;

(c) Demonstrate that land tenure is the same as that presented in the project area. In the case of including areas with different tenure figures, the project holder shall demonstrate that historically the transformation of land cover has not been impacted by the type of tenure;

(d) Demonstrate that the cultural and socioeconomic conditions (applicable legislation, governance system, land use) are like those present in the project area.

8.2 Carbon pools and GHG sources

8.2.1 Carbon pools

The Intergovernmental Panel on Climate Change (IPCC) estimates changes in carbon stocks in the following pools: aboveground biomass, belowground biomass, dead wood, litter, and

[31] The mobility distance of agents can be determined from secondary studies or primary information gathering (Participatory Local Assessment - PLA).

soil organic carbon. For the application of this methodology, carbon pools are described as shown in

Table 1.

Table 1. Carbon pools

Carbon pool		Description
Live Organic Matter	Aboveground biomass	All aboveground living biomass, including stems, stumps, branches, bark, seeds and foliage.
	Aboveground aquatic biomass	Biomass present in the littoral zone of aquatic ecosystems from aquatic vegetation and differentiated according to their life form. It is recommended to consider the dominant morphospecies for the calculation of biomass.
	Belowground biomass	All living root biomass. Fine roots less than 2 mm in diameter are excluded, because they are often not empirically distinguishable from soil organic matter.
Dead Organic Matter	Deadwood	Includes non-living aboveground wood, whether standing or fallen, including dead roots and stumps 10 cm or more in diameter.
	Litter	It comprises all non-living aboveground biomass (leaves, branches and fruit shells) in various stages of decomposition. It includes layers of debris (fumic and humic).
Soil Organic Carbon	Organic carbon in soil and sediments	Includes organic carbon in mineral and organic soils at a specific depth selected by the project holder.
Biodiversity	Hydrobiological communities and floodplain fauna	It includes the carbon content in biomass represented in deposits other than terrestrial aboveground biomass, aquatic aboveground biomass, belowground biomass, dead organic matter, litter, or organic carbon in soil and sediments.

Carbon pool		Description
		It includes vertebrate fauna biomass and other hydrobiological components contained in deposits associated with soils and/or aquatic covers (hydrobiological) and another selection for transition covers

The selection of carbon pools to quantify changes in carbon reduction and/or removal at the project boundaries is shown in Table 2.

Table 2. Carbon pools selection

Carbon pool	**Required (Yes/No/Optional)**	**Explanation / justification**
Aboveground Biomass	Yes	The change in carbon content in this pool is significant, according to the IPCC.
Aboveground aquatic biomass	Optional	The carbon stocks in this pool are expected to increase because of the project's restoration activities.
Belowground biomass	Yes	The change in carbon content in this reservoir is significant according to the IPCC.
Deadwood and litter	Optional	The amount of carbon stored in this pool may increase due to project activities.
Soil Organic Carbon	Yes	The change in carbon content in this pool is significant according to IPCC, 2006.
Biodiversity	Optional	The amount of carbon stored in this pool may increase due to project activities.

Project holders may choose not to consider the carbon deposits listed in the table (above) as *optional*, provided they provide transparent and verifiable information demonstrating that such a choice will not lead to overestimation or underestimation in the reduction/removal of quantified GEI emissions by the project[32].

8.2.2 GHG sources

The emission sources and associated GHGs are presented in Table 3.

Table 3. Emission sources and GHGs in the baseline and project scenario

Anthropic activities				
Source	**GHG**		**Selection**	**Explanation/Justification**
Woody biomass combustion	CO_2	Carbon Dioxide	No	CO2 emissions due to woody biomass combustion are not quantified as carbon stock changes according to the IPCC.
	CH_4	Methane	Yes	Shall be included if the presence of fires/burns was identified during the monitoring period (e.g. woody biomass burning due to site preparation as part of land preparation).
	N_2O	Nitrous oxide	Yes	Shall be included if the presence of fires/burns was identified during the monitoring period (e.g. woody biomass burning due to site preparation as part of soil preparation).
Hydrological regime alteration	CO_2	Carbon Dioxide	Yes	Shall be included if land use changes are observed within the project boundaries.
	CH_4	Methane	Optional	Inclusion is suggested if it is identified that wetland transformation activities in the project scenario generate an increase in methane emissions.
Use of fertilizers	CO_2	Carbon Dioxide	No	CO2 emissions due to fertilizer application are not quantified as changes in carbon stocks
	CH_4	Methane	No	CO2 emissions due to fertilizer application are not quantified as changes in carbon stocks

[32] Except for exclusion of biodiversity

Anthropic activities				
Source	**GHG**		**Selection**	**Explanation/Justification**
	N_2O	Nitrous oxide	Yes	Nitrous Oxide emissions must be included if fertilizers are applied in the baseline scenario and are expected to be reduced in the project scenario

8.3 Temporal boundaries and quantification period

Project temporal boundaries correspond to the periods during which project activities are carried out and GHG emission reductions and removals are quantified.

The project temporal boundaries shall be defined considering the following:

(a) The start date of the project;

(b) The period of quantification of the reductions/removals; and

(c) The monitoring periods.

The reduction of emissions and/or removals attributable to project activities are accounted for during the quantification period of the project. That is, the period during which the project holder quantifies the reductions/removals of greenhouse gas emissions, measured against the baseline scenario.

The quantification period, during verification, corresponds to the monitoring period.

9 Characterization of continental natural wetlands

9.1 Evaluation of hydrometeorological information

The project holder shall characterize the continental natural wetlands by combining the cartographic base with evaluation of hydrometeorological information and physical-chemical variables.

The suggested methods to carry out such characterization are presented below. However, the project owner may apply different methods, as long as they correspond to validation of reliable and relevant information.

9.1.1 Obtaining the information

To complete the characterization of the hydrometeorological variables, climatological, limnological and limnometric stations shall be taken into account, which have a recording period that allows obtaining data with the required statistical rigor. Climate stations that are located both within the project boundaries and in areas close to the area within the project boundaries can be considered. The variables on which information shall be obtained are the following: precipitation, temperature, solar radiation, sunshine, wind, atmospheric pressure, relative humidity, evaporation, level, flow and sedimentological information.

Although measurement stations for both hydrological and meteorological variables are used to collect reliable and useful information for analysis with different objectives, these will always be restricted to a certain uncertainty and error in the measurement. Therefore, pre-processing of hydrometeorological information is required, in order to obtain assured series, or with a high level of quality, in accordance with the World Meteorological Organization (WMO).[33]

9.1.2 Analysis of systematic errors

Systematic errors are erroneous measurements that are reproduced in the same way and repetitively. Generally, they are caused by a defect in the instrument and/or the measurement is made. For information pre-processing, the possible presence of systematic errors can be evaluated through the calculation of a moving average, applied to the time series. A calculation window for the 30-day moving average shall be considered, taking the average of the consecutive data found for that time, ignoring missing data. This criterion is useful for evaluating possible changes in the mean due to systematic failures in station measurements such as repeatability of outliers.

9.1.3 Data analysis or data quality control process

Depending on the variable of interest, relevant criteria shall be applied to define whether a data is atypical or not, within a time series. The analysis of atypical or anomalous data shall be carried out for time series, and a percentage threshold above which a data could be accepted as atypical shall be used, considering the 95% and 5% percentile as the minimum limits to consider an event as anomalous.

The GHG project holder shall demonstrate that the analyzed variables are appropriate to carry out the analysis of atypical data.

[33] WMO,2019. Manual of the Global Framework for Management of High-Quality Climate Data. WMO No. 1238, Genève 2, Switzerland

9.1.4 Analysis of consistent and homogeneous periods

The quality of hydrometeorological information is defined by the degree of homogeneity and consistency of the time series.

One way to determine possible problems of homogeneity and consistency in time series is by simple visual inspection by directly graphing the data record. In this way, it is possible to notice significant changes and extreme outliers, in addition to verifying the general behavior of the series. To objectively identify changes in statistical parameters, parametric or non-parametric tests can be used, which can also indicate whether or not there is a trend in the series. Tests such as mass and double mass can be performed for precipitation and flow. It is equally valid to use statistical hypothesis tests such as the Pettit Test.

9.1.5 Data processing

The objective of this stage is to generate the necessary information at both spatial and temporal level, completing any missing information in the downloaded stations records, and also generating the spatial information through a geostatistical conceptualization.

9.1.6 Filling missing data

Filling is applied to time series that present missing values, the estimation of which is necessary for their application to different types of analysis, providing better results compared to those obtained when calculated based on incomplete data sets. In general, the longer the period to be estimated, the lower the level of confidence that can be assigned to the estimates [34].

9.1.7 Hydrological modeling

Hydrological and hydraulic modeling can be managed on a monthly time scale, using a semi-distributed hydrological model, such as (SWAT) at a basin spatial scale. There are several models, applicable according to the data available, that can be used through a two-dimensional hydraulic model. Additionally, there are models that calculate water balance at a pixel scale, for which input variables need to be provided in raster format (such as INVEST WATER YIELD). The time series required for modeling shall be manage a daily temporal scale.

[34] WMO,2018. Guide to Climatological Practices. WMO-No. 100. World Meteorological Organization (WMO). Geneva, Switzerland.

9.1.8 Spatial Data processing

The project holder may use a hydrological model for the appropriate hydro-climatological characterization of the areas within the project boundaries

This shall be carried out using the necessary variables for spatial data processing. Spatial data processing is an critical component for the representation of the climatology of the constructed hydrological models, where different interpolation algorithms are compared and evaluated based on the variable being spatialized. Algorithms such as: Inverse Distance Weighting (IDW) with a weight equal to 2, External Kriging Drift (KED), Regressive Kriging (Kreg), and Multi-Source Weighted Ensemble Precipitation (MSWEP) data blended with the Double Smoothing (DS) algorithm can be used for this purpose.

9.1.9 Physicochemical variables analysis

To carry out the physicochemical analysis of continental natural wetlands, project holder can consider only some variables contemplated in this type of ecosystems. However, it is suggested that at a minimum, the characterization be carried out using the key variables stipulated by the protocols and/or regulations of each country. In Table 4, a list of the main variables that can be included is presented:

Table 4. Physicochemical analysis variables

Variable type	**Variable**
Physical variables (for unmanaged wetlands)	▪ Water level (also considered a hydrometeorological variable) ▪ wetland surface area ▪ Total depth ▪ Water temperature ▪ Height of the water table
Aquatic biota	▪ Secchi Transparency ▪ Flow
Chemical variables	▪ pH ▪ Dissolved oxygen (DO) ▪ Nutrients: Nitrogen (N) and Phosphorus (P) ▪ CO_2 and CH_4 flow ▪ Organic Carbon (OC) ▪ Total coliforms (TC) ▪ Chemical Oxygen Demand (COD) ▪ Dissolved and suspended solids (TDS and SS) ▪ Turbidity

In situ measurement of the variables, as well as the taking of samples for *ex situ analysis* and laboratory analyses, shall guarantee compliance with current standards and systems required for quality assurance.

9.1.10 Sampling areas

For the selection of sampling areas, the following criteria shall be considered:

(a) Previous information obtained from previous hydrological modeling campaigns, within the project boundaries;

(b) Covers associated with natural plant covers, other than forest, and semi-natural areas in the project area, identified with the appropriate cartographic scale;

(c) Sectors located in lentic systems both near the banks and in the lake area and in lotic systems of different orders [35];

(d) Sectors in which actions related to fishing, restoration, connectivity, conservation corridors are carried out, as well as sectors close to hydrometeorological and/or limnometric stations in the area.

Based on these criteria and using GIS tools, land cover analysis and secondary information shall be used to determine aspects related to literals a) to d) above.

9.1.11 Sampling and Data analysis

Sampling shall include environmental characteristics and *in situ measurements*. In lotic systems, measurements shall be taken at three points in the channel area (from the bank to the center). In lentic systems, measurements shall be conducted through vertical profiles in the water column (subsurface, mid-photic zone, limit of the photic zone, mid-floor) and, if observed, the aphotic zone before the bottom. In addition, the wind speed shall be measured (according to the Beaufort nanometric scale). In lotic systems the flow shall be estimated while in lentic systems, both surface water transparency and total depth shall be measured.

Data Processing and analysis. Along with the quantitative results, a descriptive and exploratory analysis shall be presented, using statistics of central tendency, absolute and relative dispersion. With the variables considered in monitoring, correlation analysis can be used to prioritize variables for a subsequent multivariate statistical analysis such as: principal components, correspondences, clusters, among others.

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[35] Horton, R. E. (1945). Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. Bull. Geol. Soc. Am., 56: 275-370.

With these analyzes you can describe or explain the relationship between the variables and the sectors evaluated. For exploratory analysis of information, the use of free software such as Past, R, Biodiversity, InfoStat, among others, is recommended.

10 Biodiversity characterization

Biodiversity characterization is optional. It shall be completed if The project holder contemplates the inclusion of biodiversity in carbon stocks, for the calculation of changes in carbon stocks in the project.

For this purpose, it is suggested that the analyzes include, at least, the most representative groups or biological communities of the ecosystem, prioritized based on the geographical area, the size of the wetland and/or ecosystem services, among others.

Some of the suggested groups are: (a) Aquatic biota: Phytoplankton, phycoperiphyton, zooplankton, macroinvertebrates (associated with vegetation and/or benthic), macrophytes and fish, and (b) Amphibian and/or terrestrial biota: Insects, birds, amphibians, reptiles, mammals and vegetation.

10.1 Sampling

For the characterization of the biological groups of birds, reptiles and mammals, sampling shall consider the land cover approved under the categories defined by the IPCC. Through a GIS analysis, the polygons in the project area shall be identified by types of vegetation: woody, forest areas, grasslands, crop areas, grasslands and areas of the water mirror and beaches.

According to the diversity of habitats (according to the coverage map) and the representativeness of the analysis, the operational viability for monitoring and articulation with the other carbon deposits and project activities shall be considered.

All of the prioritized biotic groups shall be characterized, based on the required sampling (Table 5) and subsequent analysis, their composition and structure (abundance measurements and diversity indices. When possible, biomass and/or allometric measurements and the biogeographic aspects of the species (native, endemic, introduced, invasive, naturalized, etc.).

Similarly, the threat categories established by the International Union for Conservation of Nature (IUCN) can be included: Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Endangered Critical (CR); as well as the commercial and/or cultural aspects in the wetland area and the migratory habits of the species found.

Table 5. Sampling of biodiversity communities

Biotic Group	Method
Phytoplankton	Integrated of three samples obtained at different depths of the photic zone (subsurface, middle part and lower limit), using a Van Dorn bottle.
Phycoperiphyton	In 10 submerged substrates or at the water-air interface, by brush removal, using 9 cm^2.
Zooplankton	Integrated from three samples obtained at different depths of the photic zone (subsurface, middle part and lower limit), using a 30L Schindler-patalas bottle.
Aquatic macroinvertebrates	In a coastal area with the presence of aquatic macrophytes, in a quadrant of 1 m^2 of said plants. Collection by removal with a triangular net and manual squeezing.
Aquatic macrophytes	Through direct observation in a transect perpendicular to the shore, made up of 10 quadrants of 1 m^2 from the limnetic zone to the shore). Modified from Ramos et al. (2004).
Riverside vegetation	Through direct observation in rectangular plots of 500m^2.
Birds	Visual and auditory detection through transect routes of variable length (depending on the size of the cover and accessibility conditions), using binoculars and a recorder. In addition, a photographic record of the species was made. The records were made during the hours of greatest activity of the birds (5:30 to 9:30 and 16:00 to 18:00, for a total of 6 daily hours of observation.
Herpets	Intensive free search transects by visual encounter (VES) for seven (7) hours a day, according to Lovich et al. (2012), McDiarmid et al. (2012) and Heyer et al. (2014): daytime sampling from 3:00 p.m. to 6:30 p.m. focused mainly on the visual exploration of the available microhabitats and nighttime sampling from 6:30 p.m. to 10:00 p.m. consisting of visual exploration of the soil and vegetation and auditory recordings. It is suggested that the transects be complemented with non-lethal traps for semi-aquatic turtles (2 in bodies of water in each area) for 5 hours.

The analysis of the structure of biodiversity communities can be established based on the following metrics:

(a) Density (phytoplankton in ind/mL, phycoperiphyton in ind/cm², zooplankton in ind/L and aquatic macroinvertebrates in ind/m²),

(b) Abundance (as number of individuals for riparian vegetation, birds and herpets) or Percent Cover (for macrophytes).

(c) Specific wealth

(d) Shannon Diversity Index (1949)

(e) Simpson's dominance index (1949)

(f) Pielou 's equity or fairness index (1969)

On the other hand, the identification and description of High Conservation Values (HCVs), from the species to the landscape level, allows subsequent evaluations to focus on the variations of said HCVs and the reduction of pressures on biodiversity.

The spatiality of the analyzes shall be proposed from a cartographic base or geographic information system that allows considering, among others, the geomorphological and socioeconomic aspects of the wetland, so that the characterization and monitoring represent as much as possible its different habitats, coverage and uses and temporality, according to the climatic variations of the study area, due to the changing dynamics (mainly at a physical, chemical and ecological level) that these variations impose on the wetlands.

For all groups or communities, it is recommended that field, laboratory (when applicable) and analysis methodologies (including statistical analysis) are carried out following standardized, appropriate methods and by competent and suitable professionals in each biological group.

However, because vegetation is one of the most important components in the delimitation of wetlands (mainly macrophytes and floodplain vegetation), it is suggested to consider both components of this community within the characterization of biodiversity. for which you can follow the methods described below.

10.1.1 Macrophyte field phase

The estimation of the percentage of coverage of each of the macrophyte species present can be done semi-quantitatively. For this, ten (10) quadrants of 1 m ² are used in each sector, using a 1 m x 1 m square. The quadrants are located perpendicular to the edge of the body of water in lentic systems, and in the case of lotic systems, the extension of the aquatic plant mat is evaluated to estimate whether the quadrants were located perpendicular or parallel to the bank. In cases where it is arranged in parallel, one or two quadrants located above the water basin and the remaining quadrants towards the shore shall be secured, in order to cover the water-land transition zone.

The transects are located in the defined areas trying to cover the greatest number of biotypes present in the 10m2 area. In each quadrat, the percentage cover of the species present within the quadrat is estimated, the biotope is recorded (submerged wanderer, floating wanderer, rooted with submerged leaves, rooted with floating leaves, rooted in transition zones, fixed on stones in current systems)31 and this information is recorded in field forms. In addition, data on physicochemical variables such as DO, conductivity, pH and depth shall be collected in situ.

10.1.2 Field phase of floodplain vegetation

A minimum one (1) survey per sampling sector is required, for both lentic and lotic sectors. In each survey, an inventory of all woody stem and tree species (height greater than 5 m) shall be carried out.

For the characterization of woody shrub species (heights between 1.5 to 5m), two 5 x 5m subplots are used at different points of the plot. However, if no shrub species are identified at the sampling site, the inventory of species with heights between 1.5 and 5m shall be conducted throughout the survey and which will correspond to the shrub stratum.

Finally, herbaceous species characterization shall be conducted by establishing 2 subplots of 2 x 2m located inside the main plot. In all plots (and subplots) a species inventory is carried out and the cover of each species is estimated from the crown projection (in tree and shrub species) and percentage of cover (in herbaceous species).

Tree individuals have their diameter at breast height (DBH), total height and the height of the first branch measured. In the formats designed for the tree layer of each plot, the soil moisture value (%) is recorded. Additionally, other important characteristics in the area, such as the presence and estimated coverage of vines, lianas, climbers and epiphytes and evidence of observable anthropic intervention, shall be observed.

10.1.3 Taxonomic identification of samples

Plants that cannot be identified in the field shall be collected and preserved and subsequently use taxonomic keys to obtain taxonomic identification. This in order to carry out biodiversity and structural analysis of the vegetation, it will also serve to obtain the invasive potential from the lists of invasive species (mainly for aquatic vegetation).

Additionally, nomenclatural validation of scientific names shall be carried out, for which tools such as TROPICOS.ORG and TNRS (Taxonomic Name Resolution Services) can be used.

The list of species also allows establishing the threat category in accordance with the categories established by the International Union for Conservation of Nature (IUCN[36]).

10.2 Macrophyte data analysis

With the list of species and their respective coverage, the average coverage of each species for each of the transects is determined. Once this calculation is made, the coverage (%) of life forms (biotypes) per transect is estimated (Equation 1) and the proportion of biotypes per transect (Equation 1).

$$\%Cov\ biotype\ n = \sum(\%Cov\ spp.\ biotype\ n) \qquad \text{Equation 1}$$

Where, % Cov biotype n is equivalent to the coverage (%) of a given biotype in the transect; and ∑ (% Cov spp. biotype n) is the sum of the average coverage of all species of the same biotype. The value of this variable can range between 0% and 100%; Values close to 0 indicate low dominance of the biotype while values close to 100 indicate high dominance of the biotype.

$$PB = \frac{\#\ biotypes\ per\ transect}{\#\ total\ of\ biotypes} \qquad \text{Equation 2}$$

Where, PB is the proportion of biotypes in the transect. The total # of biotypes will always be seven (7), since it is the number of biotypes worked on in the methodology. The PB values vary between 0 and 1, with zero being zero representativeness of biotypes in the transect and 1 being high representativeness of biotypes in the transect.

To determine the proportion of species with invasive potential, the average coverage of the species identified with invasive potential is added and divided by the total coverage of species recorded in the transect. The value of this variable can be between 0 and 1. Values close to zero indicate a low proportion of species with invasive potential, while values close to 1 indicate dominance of species with invasive potential in the transect. (Equation 3).

[36] IUCN. (2021). The IUCN Red List of Threatened Species. Retrieved from https://www.iucnredlist.org/e

$$PPI = \frac{Cov\ \%\ spp.\ with\ invasive\ potential}{Cov\ \%\ total\ spp} \qquad \text{Equation 3}$$

On the other hand, species richness shall be estimated for each of the sectors and the Shannon diversity index, Dominance index, Equity index and Margalef´s richness index (Table 6). For those analyses, free software such as PAST, EstimateS, and R, among others, may be used.

Table 6. Diversity indices

Indices	**Index formula**
Shannon Diversity	$H = -\sum_i \frac{ni}{n} ln \frac{ni}{n}$ Equation 4
Dominance	$D = \sum_i \left(\frac{ni}{n}\right)$ Equation 5
Evenness	$Evenness = \frac{H}{\ln S}$ Equation 6
Margalef Wealth	$Margalef = \frac{(S-1)}{\ln(n)}$ Equation 7

Where $\boldsymbol{n}$ is the total number of individuals; $\boldsymbol{ni/n}$ is the proportion of individuals of species $\boldsymbol{i}$ relative to the total number of individuals (the relative abundance of species $\boldsymbol{i}$) and $\boldsymbol{S}$ is the total number of taxa.

The Shannon index typically range from 0 and 5. A, higher value indicates greater diversity of a sector. Values above than 3 are indicative of sectors or areas with high diversity. In the case of the other indices, values range between 0 and 1, where zero represents the lowest level of evenness, dominance or richness and 1 being the greatest.

10.3 Analysis of Floodplain Vegetation Data

Vegetation coverage assessments are based on structural calculations, such as basal area, diameter structure and heights distribution.

The diametric structure is analyzed by plotting histograms of abundance vs. diameter class in 8 diameter classes (10 cm width) [37]. The vertical structure is determined by plotting histograms of abundance vs. height class in 10 height classes (5 m width); the first height class (ie 1.3-5 m,

[37]According to the method proposed by Silvertown & LovettDoust (1993)

5-10 m). Additionally, the number of trees, basal area and biomass are plotted in relation to the height above sea level of each plot.

To estimate the heights of individuals for which direct measurements are not available, a Weibull-type distribution model is used.

10.3.1.1 Floristic composition

The characterization of the floristic composition is carried out through surveys at the family and species level. To evaluate the ecological importance of families, the Importance Value Index (IVI)(Equation 8) shall be calculated, based on relative density (Equation 9), relative dominance (Equation 10) and relative frequency (Equation 11)[38]

$$IVI_f = De_r + Do_r + Fr_r \qquad \text{Equation 8}$$

Where:

IVI_f	=	Family importance value index
De_r	=	Relative density
Do_r	=	Relative dominance
Fr_r	=	Relative frequency

$$De_r = (\text{number of individuals in a family})/(\text{number of total individuals})*100 \qquad \text{Equation 9}$$

$$Do_r = (\text{Aerial biomass per family})/(\text{Aerial biomass for all families})*100 \qquad \text{Equation 10}$$

$$Fr_r = (\text{number of species in a family})/(\text{total number of species})*100 \qquad \text{Equation 11}$$

To determine the importance of each species, the Importance Value Index (IVI) shall be calculated for the species present in each type of vegetation cover. The IVI (Equation 12) is obtained from the sum of the relative abundance (Equation 13), relative dominance (Equation

[38]Adapted from Mori, S., Boom, B., de Carvalho, B., & Dos Santos, T. (1983). southern Bahian moist forest. The Botanical Review, 49(2), 155-232.

14) and relative frequency (Equation 15) of each species [39]; The calculated BA was used as a dominance criterion.

$$IVI_{sp} = Ab_r + Do_r + Fr_r$$ Equation 12

Where:

IVI_{sp}	=	Ecological importance value index by species
Ab_r	=	Relative abundance
Do_r	=	Relative dominance
Fr_r	=	Relative frequency

Ab_r = (number of individuals of a species)/(number of total individuals)*100 Equation 13

Do_r = (Aerial biomass per species)/(Aerial biomass for all species)*100 Equation 14

Fr_r = (frequency of a species)/(Sum of all frequencies)*100 Equation 15

10.3.1.2 Floristic diversity

Diversity α.

In order to characterize floristic diversity, the indices of Shannon's Equity (E) (Equation 16), Simpson's dominance (D) (Equation 17), as well as the richness or number of species in each of the sampled units shall be used[40].

$$H' = \sum -(f_i ln f_i)$$ Equation 16

[39] Lamprecht, H. 1990. Forestry in the tropics/Forest ecosystems in tropical forests and their tree species - possibilities and methods for sustained use. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. Eschborn.
[40] Magurran, A.E. 1989. Ecological Diversity and its Measurement. Princeton University Press, Princeton, NJ 179 p.

$$D = \sum f_i^2$$ Equation 17

Where f_i is equivalent to the relative abundance of the species.

Likewise, Fisher's Alpha index can be calculated (Equation 18), recommended for comparing different types of coverage, as it is less sensitive to sample size[41].

$$S = \propto ln\left({(1+N)}/{\propto}\right)$$ Equation 18

Where S is the number of species, N the number of individuals, and α represents the base of the parameter.

Diversity β.

The Jaccard index (Equation 19) is a qualitative method that expresses the similarity between two sites only considering the species composition; it also relates the number of shared species to the total number of exclusive species. Additionally, this index gives equal weight to all species regardless of their abundance and therefore gives importance to even the rarest species.

$$I_j = {c}/{(a+b+c)}$$ Equation 19

Where: a= number of species in site A, b= number of species in site B, and c= number of species present in both sites A and B, that is, they are shared.

The range of this index goes from zero (0) when there are no shared species, to one (1) when the two sites share the same species. This index measures differences in the presence or absence of species.

10.4 Statistical analysis

To present the results of the biotic information, bar graphs are constructed that represent the frequency of the biological components and that allow the different monitoring sectors of the wetland to be compared.

[41]Condit et al. (2004) Condit R, Aguilar S, Hernandez A, Perez R, Lao S, Angehr G, Hubbell SP, Foster RB. Tropical forest dynamics across a rainfall gradient and the impact of an El Niño dry season. Journal of Tropical Ecology. 2004; 20:51–72. doi :10.1017/S0266467403001081.

Additionally, ecological diversity indices (Simpson's dominance, Margalef's richness, Shannon's diversity and Hill's uniformity) are calculated for each community at each sampling site.

With the result of the indices, it is suggested to perform ordering analyzes that require having a number of variables equal to or less than the number of places evaluated [42]. Variables shall be selected based on their explanatory power, avoiding those that are highly correlated, and those that explain the greatest percentage of the variance of the data.

For multivariate analyses that seek to determine the most representative variables, the following steps are suggested: 1) Pearson correlation calculations to eliminate variables with correlations greater than 0.7; 2) calculation of the coefficient of variation to remove variables with coefficients less than 20%; and 3) if the variables have different scales, carry out the standardization process.

The selected variables are used for other multivariate analyses that allow biotic and abiotic information to identifythe relationships between the community structure and the wetland water quality. The most commonly used analyses for this purpose are: Principal Components Analysis (PCA), Canonical Correspondence Analysis (CCA), cluster analysis, discriminant analysis, non-metric multidimensional scaling (NMDS), among others.

11 Identification of the baseline scenario and additionality

To demonstrate that project activities generate Verified Carbon Credits (VCCs) that represent additional GHG emission reductions or removals, the project holder shall follow the guidance contained in the BCR Guidance "Baseline and additionality"[43]. The guidance contains provisions relating to additionality and baseline for projects under the BCR Standard[44].

On the other hand, GHG project holders shall demonstrate that emission reductions (or removals) do not correspond to emission reductions attributable to the implementation of legally required actions.

[42] Kenkel, N. (2006). On selecting an appropriate multivariate analysis. Department of Botany, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

[43] https://biocarbonstandard.com/tools/additionality.pdf

[44] The BCR Baseline and Additionality Guidance is a mandatory guidance covering the requirements established to ensure a realistic and conservative estimate of baseline emissions; it also provides requirements to ensure that activities are additional in all eligible sectors.

12 Identification of Transformation Drivers

To identify the drivers of transformation, a prospective analysis is proposed. This method includes action, appropriation anticipation as the basis for establishing future starting points[45]. It is based on hierarchies of influence and dependence "of" and "on" each of the variables, avoiding bias among the identified components[46].

The identification of the drivers of transformation is carried out in two steps:

(a) Literature review of the project area;

(b) Creation of concerted spaces with local stakeholders, including participants representing civil society, trade unions or productive sectors, local organizations and the public sector.

To define the influence and dependence of the transformation drivers in the project area, the use of the MICMAC[47] software is suggested. In MICMAC each of the identified drivers are added (including an acronym and its conceptual definition), for their subsequent qualification.

Table 7. Criteria for rating transformation drivers based on stakeholder input and available secondary information.

Score	Influence
0	Null
1	Low
2	Moderate
3	High

Based on the criteria assessed and the scale described in Table 7, the values are placed within the Direct Influence Matrix (MID), considering the influence of driver A on the others (dependence), and the dependence of driver A exerted on the others (influence), described in Figure 1.

[45] Martín, J.A. (1995). Prospectiva tecnológica: Una introducción a su metodología y a su aplicación en distintos países. Madrid: Fundación Cotec para la Innovación Tecnológica. 55 p.
[46] Senhadji-Navarro, K., Ruiz-Ochoa, M. A., & Rodríguez Miranda, J. P. (2017). Estado ecológico de algunos humedales colombianos en los últimos 15 años: una evaluación prospectiva. Colombia forestal, 20(2), 191-200
[47] Freely available software. It is suggested to use the version 6.1.2 2003/2004.

The result of the analysis will be a graphical output in the form of a Cartesian plane where, based on the spatial location of the different drivers, the categorization can be identified. This will inform the prioritization criteria for future actions.

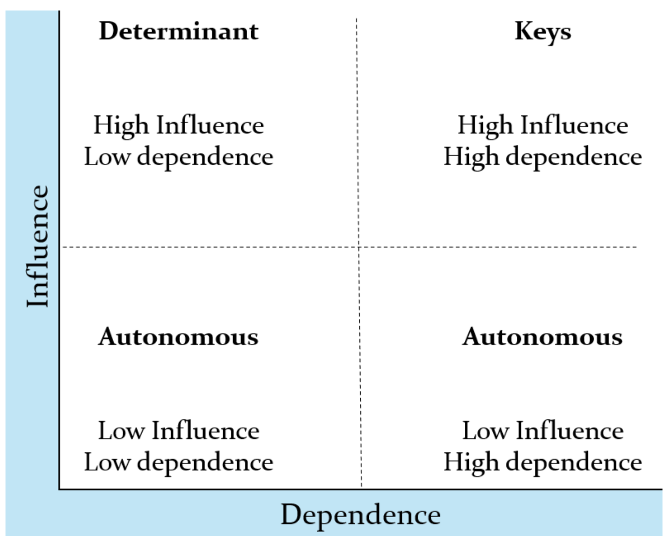
Figure 1. Direct Influence Matrix (MID) for Data capture of Transformation Driver ratings.

		Over				
		Influence				
	Dependence	Driver	D1	D2	D3	D4
From		D1				
		D2				
		D3				
		D4				

Source: Protocol for estimating carbon content in wetlands of the middle and lower Magdalena

Those drivers with low influence and dependence will be considered autonomous, while those with low influence and high dependence will result from certain actions. Determining drivers will be those with high influence and low dependence, whereas key drivers (where efforts can be concentrated) will have high influence and dependence, as shown in Figure 2.

Figure 2. Interpretation of the influence and dependence map from prospective analysis within the MICMAC framework.



Source: "*Protocolo para la estimación de contenidos de carbono en humedales del Magdalena medio y bajo*"

To interpret the results, both the indirect influence map (for prioritization) and the indirect influence graph (for determining interactions) shall be considered. These are derived from the direct analysis based on stakeholder ratings. The results of these analyses shall be used to identify project activities that can mitigate the transformation pressure on natural coverages.

On the other hand, geographic information systems (GIS) based analysis can identify transformation factors in ecosystems. By integrating geospatial data on environmental variables, such as land cover, land use, water quality, , with economic and social data, spatial patterns and relationships are visualized. For example, proximity analysis, density analysis, spatial interpolation, correlation analysis, among others.

13 Project activities

Conservation and restoration activities shall be designed based on an assessment of environmental and social conditions in the project area. The design of each project activity shall include, at a minimum, the following:

(a) Activity ID;

(b) Relationship of activity to GHG emissions reduction and/or removal;

(c) Consultation mechanism for the definition of project activities and participatory construction aspects (if applicable);

(d) Responsibility and role of the actors involved in the implementation of the activity;

(e) Implementation schedule;

(f) Indicators to report the progress of the activity: name, type[48], goal[49], unit of measurement and person responsible for the measurement.

Project activities shall be aimed at promoting connectivity and rehabilitation of aquatic and terrestrial ecosystems to contribute to the conservation of species and livelihoods of local communities. Listed below are some of the activities that can be implemented by the project holder in accordance with the GHG mitigation objective.

13.1 Conservation activities

- Ecological restoration actions of degraded areas, for example the establishment of herbaceous plants, shrubs, trees, vines. As well as complementary strategies that

[48] Output, product or impact
[49] Expected value and time for compliance

include bird perches and bat shelters, among other actions that promote ecosystem restoration;

- Use of alternative energies (wind, photovoltaic, biogas) to reduce pressures on natural plant covers;
- livestock waste to produce compost and use it to improve soils;
- Installation of infrastructure for livestock and nutritional management in temporary confinement (semi-stall management for hours/day) in order to reduce soil compaction in natural areas and pastures;
- Productive alternatives such as fish farming in ponds;
- Unclogging of pipes and removal of invasive species;
- Rehabilitation of terrestrial and/or aquatic habitats;
- Technical support in production processes, management of solid and liquid waste and possible practices for its subsequent use.

13.2 Restoration activities

Afforestation, reforestation and/or revegetation (ARR) activities [50], determined as restoration actions, in areas that have been transformed:

- Revegetation with forest systems intended for the use of wood, for posters, firewood or infrastructure in order to reduce pressures on native species;
- Establishment of mixed forage banks intended for the production of food for livestock species, in order to reduce the expansion of the agricultural frontier;
- Implementation of landscape management tools. These tools can include agroforestry systems, living fences, isolated trees in pastures, biological corridors, and wood energy banks, among others;
- Recover the water circuits of the micro-basins and/or springs with different types of plant cover from different strata or growth habits to prevent soil erosion and sedimentation of water sources;
- Recovery of wetland transition zones with restoration processes, following a stratified successional method;

[50] To calculate the removals attributable to these activities, the BCR0001 methodology shall be applied.

14 Carbon stocks estimation

14.1 Delimitation of the project area and multi-temporal analysis

To delimit the project area, the following six steps are proposed: i) definition of scales, ii) delimitation of the wetland, iii) identification and selection of inputs, iv) processing of inputs, v) monitoring of activity data and, vi) consolidation and reporting.

The definition of scales proposes reaching a scale of 1:25,000 with the use of optical satellite images, such as PlanetScope, Sentinel-2 or RapidEye, with a periodicity of 2 years for monitoring and defining different temporalities for each year of analysis according to the modal regimes. Regarding delimitation, geomorphological, edaphic and hydrological elements shall be considered to initiate a delimitation process that allows establishing the project boundaries.

Subsequently, the required information shall be prepared. This includes satellite images and other information that supports and contributes to the definition of land use, such as censuses, statistics and other geographic layers with spatial information of diverse scales and sources.

With the inputs ready and available, we proceed with the digital processing of the selected images using semi-automated methods and change detection algorithms over time to calculate the relevant indicators for terrestrial and aquatic areas separately.

For images, whether satellite, optical or radar, established approaches for data preprocessing shall be applied. Table 8 and Table 9 present the information on the images suggested for the delimitation of wetlands and in general for any processing related to the application of the methodology.

Table 8. Optical satellite images

Optical satellite	Owner	Spatial resolution	Spectral resolution	Radiometric resolution	Temporary resolution	Expectation	Access type
Landsat 7	NASA USGS	30m 15m Bread	8 bands	8 bits	16 days	1999 - Current	Free
Landsat 8	NASA USGS	30m 15m Bread	11 bands	8 bits	16 days	2013 – Current	Free
Sentinel 2	European Space Agency (ESA)	10m 20m 60m	13 bands	12 bit	5 days	2015 – Current	Free
RapidEye	RapidEye AG	6.5m	5 bands	12 bit	Daily	2008	Commercial
Spot 6/7	Airbus	6m 1.5m Pan	5 bands	12 bit	Daily	2012 – Current	Commercial

Optical satellite	Owner	Spatial resolution	Spectral resolution	Radiometric resolution	Temporary resolution	Expectation	Access type
PlanetScope	Planet Labs	3m	4 bands	12 bit	Daily	2015 – Current	NICFI (Level 1) Commercial
QuickBird	DigitalGlobe	2.62m 0.65m Pan	5 bands	11 bit	1 – 3.5 days	2001 - 2015	Commercial
Pleiades	Airbus	2m 0.5m Pan	5 bands	12 bit	Daily	2011 – Current	Commercial
WorldView 4	Ball Aerospace	1.24m 0.31 Bread	5 bands	11 bit	Daily	2016 – Current	Commercial

Table 9. Radar satellite images.

Satellite Radar	Owner	Spatial resolution	Band	Polarization	Expectation	Access type
Sentinel 1	European Space Agency (ESA)	9 – 40m	c	V.V. H H VV+VH HH+HV	2014 – Current	Free
Radarsat -2	European Space Agency (ESA)	3 – 20m	c	Selective: (HH and HV) or (VH and VV) Single: (HH) Quad: (HH, VV, HV, VH) Selective Single: (HH) or (HV) or (VH) or (VV)	2005 – Current	Commercial
Kompsat 5	Korea Aerospace Research Institute (KARI)	1 – 20m	x	Single (HH or VV) Dual (HH/VV or HH/VH or VV/HV)	2013 – Current	Commercial
TerraSAR -X	German Space Center (DLR)	0.5 – 40m	x	Single (HH or VV) Dual (HH/VV or HH/VH or VV/HV)	2007 – Current	Commercial

The steps required for digital image processing using classification algorithms vary depending on the processing software or digital platform. For example, the steps for using the free- access platform Google. Earth Engine (GEE) are as follow:

(a) Upload the study area boundary file (shapefile) and search for the image catalog to use for classification.

(b) Select the image or mosaic (temporal composite of medians) with coverage of the monitoring window, the temporal interest and has an appropriate cloud cover percentage (<20%).

(c) Add the training points or areas, which the algorithm will use to classify the defined classes. These points are shapefile files created from field data or visual interpretation.

(d) Run the selected classification algorithm (supervised or unsupervised).

(e) View the classification according to the color palette inserted in the code created for the process.

(f) Export results in raster image format for post-processing in GIS software.

After obtaining the results, the process of joining multitemporal layers shall be carried out. The resulting layer is displayed in the GIS software where the attribute table is displayed to create a new field called 'Code'. The code assigned in each field will refer to the change displayed between the data of the layer from year 1 and those from year 2, corresponding to changes in land use according to the proposed indicators for wetland change detection analysis.

14.2 Stratification of natural cover in the project area

Stratification refers to the division of a heterogeneous landscape into sections (or strata) using a common grouping factor, which aims to estimate carbon pools accurately and as effectively as possible.[51]

Vegetative cover is one of the main characteristics of wetlands. This characteristic is commonly used for the identification and delimitation of wetlands, as well as for the development of classification systems. [52]Additionally, the quantification of plant biomass constitutes a key component for determining the carbon stored in wetland ecosystems and, therefore, for the application of this methodology, stratification is proposed for continental wetlands according to the type of vegetation and the characteristics. pedological.

Generally, in natural continental wetlands, the zoning of the vegetation is not homogeneous, but rather there is a transition that goes from the water mirror to the flood plain zone. For this reason, it is necessary to carry out a stratification process, with the purpose of improving the precision with respect to biomass estimates in the project.

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[51]Kauffman JB, Donato DC and Adame MF. 2013. Protocol for measuring, monitoring and reporting the structure, biomass and carbon reserves of mangroves. Working Paper 117. Bogor, Indonesia: CIFOR. Available at: https://www.cifor-icraf.org/publications/pdf_files/WPapers/WP117Kauffman.pdf

[52]US EPA. 2002. Methods for Evaluating Wetland Condition: Wetlands Classification. Office of Water, US Environmental Protection Agency, Washington, DC. EPA-822-R-02-017. Available at https://www.epa.gov/sites/default/files/documents/wetlands_7classification.pdf

The estimation of carbon content in the biomass, of natural vegetation covers, other than forest includes aquatic vegetation and transition zones between the water surface and dry land.

The project holder shall identify the strata for the baseline scenario and for the calculation of mitigation results. In this way, the precision in the estimation of GHG emissions reductions or removals is optimized. In particular:

(a) For the baseline scenario, it is usually sufficient to stratify the project area according to land use or cover categories,

(b) For the project scenario, stratification can be based on wetland conservation and restoration plans.

In areas classified as wetlands, biomass derives from two important sources depending on the type of vegetation; this is how vegetal biomass is defined, coming from non-forest type covers.

For wetland areas that are found with natural vegetation cover (non-forest type cover).

Non-forest type cover [53]: Emergent floating and rooted aquatic vegetation, found above the water surface and swamp vegetation that may include herbaceous and shrubby elements. Its features are listed below:

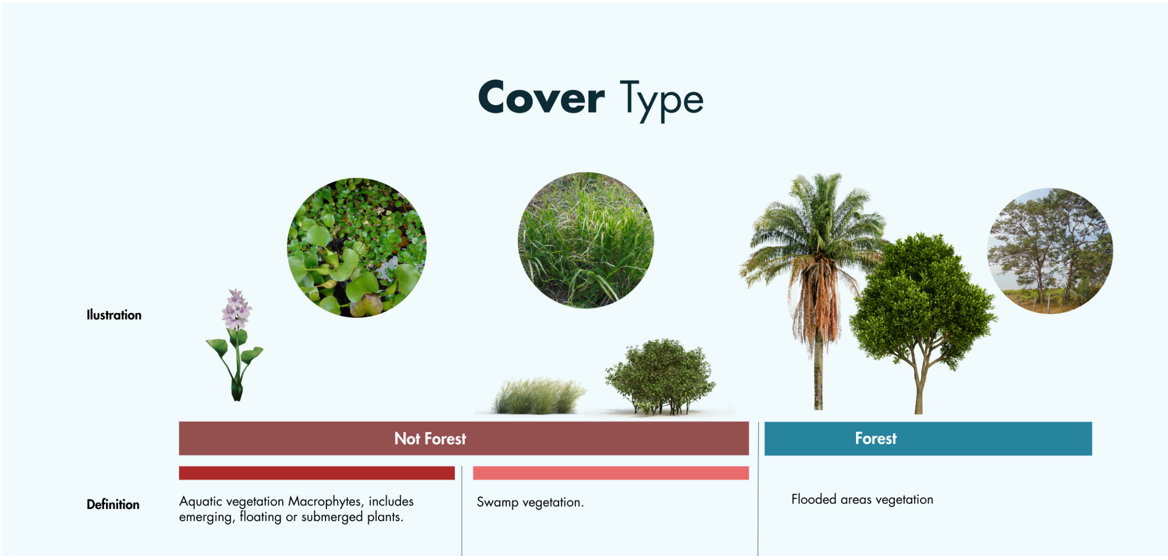
- Aquatic vegetation (macrophytes associated with freshwater wetlands).
- Herbaceous vegetation (dominated by plants with a height between 0.3 and 1.5m) and vegetation at ground level dominated by herbaceous plants with a height of less than 30cm.
- Shrub-type vegetation (plants with a height between 1.5 and 5m).

Figure 3 shows the vegetation components associated with each type of coverage.

For covers other than natural vegetation cover, on which restoration activities will be carried out, stratification shall be performed based on the cover types and land use type, using the categories defined by the CORINE Land Cover methodology, or that applicable in the country in which the project is developed.

[53] This methodology only includes “Non-forest type” coverage.

Figure 3. Vegetation components in the strata for carbon quantification in wetlands[54]



Source: "*Protocolo para la estimación de contenidos de carbono en humedales del Magdalena medio y bajo*"

14.3 Field sampling design

To estimate the carbon stock in each of the identified strata, it is necessary to establish temporary sampling plots, the number of plots depends on the number of strata within the project boundaries. These plots will be used to monitor changes in carbon stocks. All plots shall be properly numbered, georeferenced and mapped within the project boundaries.

14.3.1 Sampling plots size or sampling units

According to the statistical stratified sampling design, the number of sample plots shall be determined based on the required precision and its relationship to the variability of carbon stocks.

The plots shall be established perpendicular to the shore, extending from the shore towards the swamp and riparian zone (transition zone) towards the mainland, to account for strata variation. Additionally, plots shall be established during the low water period (dry period) to accurately stablish the limits. If this is not possible, it is recommended to move a few meters

[54] Andramunio -Acero et al (2024). Protocol for estimating carbon content in wetlands of the middle and lower Magdalena. Natura Colombia Foundation, Ecopetrol and Institute of Hydrology, Meteorology and Environmental Studies IDEAM. Colombia. Available at: https://natura.org.co/wp-content/uploads/2024/02/V1_Documento-metodologico-Protocolo-Carbono-Humedales-08-02-24.pdf

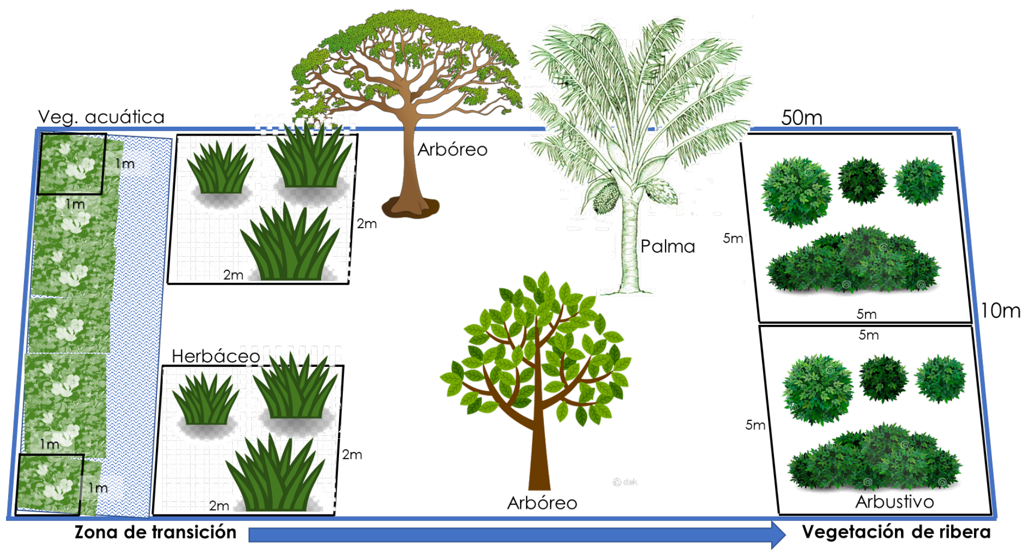
away from the water body to find an area where the demarcation stakes can be fixed, thus including the aquatic vegetation at that boundary.

Rectangular plots of 50 m x 10 m are required, for a total area of 500 m^2. This nested design allows for consideration of variations in composition and structure over time. This model is composed of a large plot with smaller subplots inside, based on vegetation study parameters.[55]

In the large plot, tree elements are monitored. Within this plot, two subplots of 25 m^2 are defined for shrub elements, two subplots of 4 m^2 each for the herbaceous stratum, and finally, two subplots of 1 m^2 each for monitoring aquatic vegetation in the water body (Figure 4).

If no shrub elements are found in the sampled area, it is recommended to collect information on this stratum in the total area of the sampling plot.

Figure 4. Plot design for the estimation of carbon deposits associated with vegetation.



Source: "*Protocolo para la estimación de contenidos de carbono en humedales del Magdalena medio y bajo*"

[55]Kauffman JB, Donato DC and Adame MF. 2013. Protocol for measuring, monitoring and reporting the structure, biomass and carbon reserves of mangroves. Working Paper 117. Bogor, Indonesia: CIFOR. Available at https://www.cifor-icraf.org/publications/pdf_files/WPapers/WP117Kauffman.pdf

14.3.2 Sampling size

To obtain the information required[56] to calculate the number of plots needed, preliminary sampling shall be carried out. The number of plots for preliminary sampling is defined by the number of strata and the chosen sampling intensity.

The sampling size (n) is estimated with the following equation:

$$n = \frac{A_i \times 10.000 \times \text{sampling intensity}^{57}}{AP} \qquad \text{Equation 20}$$

Where:

n	Number of plots required for biomass estimation; dimensionless
A_i	Size of each stratum i; ha
AP	Plot area (constant for all strata); ha.

To calculate the number of sampling plots (n), it is necessary to know the error, in percentage (E), the standard deviation (s) known from previous data, and associated with the amount of biomass per stratum, as well as the t value of *Student* for a given probability (α= 0.05).

According to UNFCCC (2010) [58], the sampling precision is required to be within 10% of the true value of the mean, with a 95% confidence level.

Kauffman JB, Donato DC and Adame MF (2013) propose a calculation to determine the number of plots [59], as follows:

$$n = \left({(t * s)}/{E} \right)^2 \qquad \text{Equation 21}$$

Where:

n = Minimum number of plots

t = t-distribution statistic for the 95% confidence interval[60]

[56] The approximate value of the standard deviation of biomass reserves, in each stratum and/or lot.
[57] The project holder shall select the sampling intensity, depending on the appropriate values for this type of sampling.
[58] United Nations Framework Convention on Climate Change (UNFCCC). 2010. Calculation of the number of sample plots for measurements within A/R CDM project activities. Available at: https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-03-v2.1.0.pdf/
[59] Kauffman JB, Donato DC and Adame MF. 2013. Protocol for measuring, monitoring and reporting the structure, biomass and carbon reserves of mangroves. Working Paper 117. Bogor, Indonesia: CIFOR. Available at https://www.cifor-icraf.org/publications/pdf_files/WPapers/WP117Kauffman.pdf
[60] t is usually 2, since at this time the sample size is unknown

s = Expected or known standard deviation of previous or initial data
E = Allowable error in the first half of the confidence interval[61]

14.3.3 Plot location on site

The location of sampling units shall be determined randomly or systematically. In the case of random sampling, with points selected at random, subjective placement of plots (center of the plots, reference points of the plot or movement of the center of the plot to a more "convenient" position) shall be avoided, adhering to the principle of randomness [62].

Field location and georeferencing using GPS ensure access and accurate location. Sampling plots shall be identified with alphanumeric code series, and their geographic position (GPS coordinates), plot location, and strata shall be recorded and archived.

14.4 Estimation of carbon content in biomass and soil

14.4.1 Variables for estimating carbon content in above ground and belowground biomass and organic matter

Table 10 presents the variables required to determine biomass in non-forest type cover.

Table 10. Definition of variables for determining biomass in non-forest cover type.

Carbon deposit	Method	Variables – direct method
Aboveground non-tree biomass (B_{ANT})	For herbaceous and aquatic vegetation, the direct method is used, which consists of harvesting at ground level (or above the water surface in the case of macrophytes) all the material found within the defined subplot or quadrant. to this end. For shrub-type vegetation, the determination of aerial biomass is carried out indirectly using allometric equations.	Fresh weight (kg) Dry weight (kg) C content (%)
Belowground non-tree biomass (B_{BNT})	aquatic vegetation, the direct method is used, in which the root system of the macrophyte is separately separated from the sample harvested for the previous item.	

[61] Obtained by multiplying the average carbon stock by the expected precision, ie *0.1 (10% precision).
[62] In the case of stratified sampling, the centroid of the selected polygon is located, and this centroid is used for the location of the plot. In the case of not being able to access the centroid, due to logistical issues, it is validated that it was within the defined stratum and the plot is located randomly.

Carbon deposit	Method	Variables – direct method
	For shrub-type vegetation, the determination of root biomass is done indirectly using allometric equations.	
Dead organic matter (DOM)	Fresh weight, Dry weight, C content (%)	

14.4.2 Estimation of biomass quantities using indirect methods

The project holder shall preferably use region-specific equations (local and national level) applicable to project location. If this is not feasible, general equations used in other regions can be employed, provided that the conditions under which they were developed are similar to those of the project area [63].

14.4.2.1 Aboveground tree biomass (B_{AT})

The B_{AT}, expressed in kilograms (kg), is calculated for the sampled tree individuals using the equation(s) that best fit the conditions of the project area. Some reference equations are presented in Table 11.

Table 11. Allometric equations for estimating area biomass of trees and palms applicable to forest cover in continental wetland areas.

Reference	Habit	Aboveground biomass equation	Origin	Variables considered
Chave *et al.* (2015)	Tree	$BA=0.0673 \times ((\rho\ D2) \times H))^{0.976}$	Tropical	DBH (D; cm), wood density (ρ; *kg/m3)*, total height (H)
Álvarez *et al.* (2012)		$B= \exp(2.406-1.289 \times \ln(D)+1.169 \times (\ln(D))^2 -0.122(\ln(D))^3 +0.445\ln(\rho))$	Tropical wet. Colombia	DBH (D; cm), wood density (ρ; *kg/m3)*
Hughes *et al.* (1999)	Palms	$B= (\exp(3.627+0.5768\ln(H^*D^2))) \times 1.02/10^6$	Palmas Mexico	DBH (D), total height (H)

Depending on the equation used, the B_{AT} is expressed in terms of diameter (D), wood specific density (ρ) and tree height (H).

[63] It is suggested to prioritize the use of allometric equations at the species, genus or family level.

Once the B_{AT} of each individual tree is calculated, the total B_{ATT} of each plot (B_{ATT}) is obtained by summing the B_{AT} of all the live trees recorded. The B_{ATT} is subsequently calculated in tons per hectare (t ha^{-1}).

14.4.2.2 *Belowground tree or root biomass (B_{BT})*

The B_{BT} is estimated from the B_{AT} for each plot[64] (Equation 22).

$$B_{BT} = 0.489 \times B_{AT}{}^{0.890} \qquad \text{Equation 22}$$

Where:

B_{BT}	=	Belowground tree or root biomass; kg
B_{AT}	=	Aboveground tree biomass; kg

14.4.3 Biomass estimation using direct methods

For non-tree cover (herbaceous and aquatic), the direct method is used, which consists of harvesting the material in the subplots defined for this purpose. It is weighed fresh, a 300-gr sample is taken. and dried in an oven at 60°C between 24 and 72 hours until a constant weight is obtained.

14.4.3.1 *Aboveground non-tree biomass (B_{ANT})*

The value of B_{ANT} is estimated from Equation 23.

$$B_{ANT} = \left({}^{DWs}/_{WWs}\right) \text{ x } WW \qquad \text{Equation 23}$$

Where:

B_{ANT}	=	dry, aboveground non-tree biomass; kg
DW_s	=	dry weight of the sample taken to the laboratory to determine the moisture content; kg
WW_s	=	wet weight of the sample taken to the laboratory to determine the moisture content; kg
WW	=	wet weight of material harvested in the field; kg

[64]Using the equation suggested by Cairns et al. (1997): Cairns, Michael & Brown, Sandra & Helmer, E. & Baumgardner, Greg. (1997). Root biomass allocation in the world's upland forests. Oecology. 111. 1-11. 10.1007/s004420050201

14.4.3.2 Belowground non-tree biomass (B_{BNT})

The value of B_{BNT} is estimated from Equation 24.

Equation 24

$$B_{BNT} = \left({}^{DWs}/_{WWs}\right) \text{ x } WW$$

Where:

B_{BNT}	=	dry, non-tree, belowground biomass; kg
DW_s	=	dry weight of the sample taken to the laboratory to determine the moisture content; kg
WW_s	=	wet weight of the sample taken to the laboratory to determine the moisture content; kg
WW	=	wet weight of material harvested in the field; kg

14.4.3.3 Biomass present in leaf litter (B_{DOM} – Dead Organic Matter Biomass)

The value of B_{DOM} is estimated from Equation 25.

Equation 25

$$B_{DOM} = \left({}^{DW_{DOM_s}}/_{WW_{DOM_s}}\right) \times WW_{DOM}$$

Where:

B_{DOM}	=	Biomass of Dead Organic Matter harvested in the field; kg
DW_{DOM_s}	=	dry weight of the sample taken to the laboratory to determine the moisture content; kg[65]
WW_{DOM_s}	=	wet weight of the sample taken to the laboratory to determine the moisture content; kg
WW_{DOM}	=	wet weight of material harvested in the field; kg

14.4.3.4 14.4.3.4 Total biomass (B_T)

The B_T, per plot, is calculated as:

[65] Separate a sample (250-300gr) for laboratory analysis (dry weight).

$$B_T = \sum_{i=1}^{n} B_{AT} + B_{BT} + B_{ANT} + B_{BNT} + B_{DOM} \quad \text{Equation 26}$$

Where:

B_T	=	Total biomass; kg
B_{AT}	=	Aboveground tree biomass; kg
B_{BT}	=	Belowground tree or root biomass; kg
B_{ANT}	=	Aboveground non-tree biomass; kg
B_{BNT}	=	Belowground non-tree biomass; kg
B_{DOM}	=	Dead organic matter biomass; kg

14.4.4 Estimation of organic carbon content in soil

To establish the carbon content in the soil, the methodology proposed by the IPCC shall be applied: Guidelines for National Carbon and GHG Inventories, Volume 4 ("Agriculture, forestry and other land uses" - AFOLU) which includes the method for quantification of carbon in wetlands (organic soils and mineral soils of continental wetlands)[66].

The proposed methodological process is presented below.

Basic information preparation

Project holder shall use official soil studies, considering the soil inventory of the project area, with its respective classification according to the USDA system (official soil cartography).

The variables to include to determine the dynamics of carbon and GHG in soils and sediments are bulk density, soil organic carbon (SOC), soil organic matter (SOM) and texture (sand, silt and clay content).

USDA/IPCC soil Clasification and its association with vegetation and land use

Using the basic information, soil classification should integrate USDA/IPCC soil classification with vegetation units and land cover/use categories, according to Table 12, below.

[66] IPCC, 2006

Table 12.USDA/IPCC soil homologation

Soils order (USDA)	Abbreviation USDA	Determinant property	Type of soil (IPCC)	Abbreviation IPCC
Histosols	IST	Organic	Organic Soils	O
Andisols	AND	Volcanic	Volcanic Soils	VC
Entisols Inceptosols	ENT EPT	Coarse texture (>70% sand)	Sandy Soils	AR
		Fine, very fine or moderately fine texture (< 70% sand)	Other Mineral soils	OM
		Aqueous humidity regime	Wetland soils	H
Mollisols	OLL	High activity clays	High activity clays	HAC
Vertisols	ERT			
Alphisols	ALF			
Ardisols	ID			
Ultisols	ULT	Low activity clays	Low activity clays	LAC
Oxisols	OX			
Spodosols	OD	Low activity clays with spodic material	Spodic	OD
Gelisols	EL	Soils frozen to their maximum depth at some time of the year	Its formation is not possible under tropical conditions	

Selection of sampling points for field validation

Through the selection of polygons, field verification is conducted to determine the feasibility of sampling, accessibility to the site (both during high and low waters levels), analysis of land cover and land use, and other considerations when taking samples.

Soil and sediment sampling (field work)

Soil sampling can be done using the "*trunk system*". This shall be carried out in the plots established for aboveground biomass sampling (vegetation plot), with three repetitions per plot. For sediments, samples shall be taken from the aquatic bottom at different depths. Similarly, , samples shall be taken at the water's edge, in sites associated with the sampling plots for aquatic vegetation.

In any case, at least three repetitions shall be done at each site. Soils and sediment shall be differentiated by organic carbon content, as only soils organic carbon. The carbon content of sediments is associated with benthic organisms and biomass residues.

To determine bulk density, soil samples are taken with known- volume sampling cylinders for this type of sampling. These samples shall be taken for each selected depth. They are placed in separate, labeled bags and included with the soil sample for SOC and texture analysis. Once the samples have been taken, they shall be sent to the laboratory for analysis.

14.4.4.1 Estimation of carbon content in soils

Soil Organic Carbon (SOC)

It is carried out in a specialized laboratory using methods such as dry or wet combustion that determine the percentage of organic carbon in the soil. The dry combustion method (Walkley – Black) is the most used for this determination. To calculate SOC in terms of tons per hectare, the thickness of the horizons, the apparent density and a correction factor for rock fragments are taken into account (FAO, 2020) [67].

To estimate the carbon contents in the soil, the bulk density Equation 27 and Equation 28 and the carbon concentration (Equation 29) are calculated at depths of 0-30 cm.

$$Bulk\ density = \frac{\text{Weith of dry soil (g)}}{\text{Soil volumen (cm}^3\text{)}} \qquad \text{Equation 27}$$

$$Volumen = \pi \times r^2 \times h \qquad \text{Equation 28}$$

Where r is the radius of the cylinder and h is the height of the cylinder.

$$C = Concentration \times (Density \times 100\ ) \times Depth \qquad \text{Equation 29}$$

To determine the carbon content, at different depths, the weighted average is calculated, determining the carbon content in each layer. The organic carbon content in the soil is then summed to the maximum required depth[68].

In cases in which the soils present limitation that prevents sampling for bulk density determination, it is recommended to apply the model defined by IGAC- IAvH (2018) [69]. This model used the characterization of a total of 929 soil profiles, correlating the texture analyzed

[67]Food and Agriculture Organization of the United Nations (FAO) (2020). Technical specifications and country guidelines for Global Soil Organic Carbon Sequestration Potential Map (GSOCseq). Rome, FAO. (also available at: https://www.fao.org/documents/card/en/c/cb0353en/).

[68]Honorio, C., Baker, T. (2010). Manual for monitoring the carbon cycle in Amazonian forests. Peruvian Amazon Research Institute / University of Leeds. Lima, 54 p.

[69]von Humboldt Biological Resources Research Institute (IavH). (2018). Analysis of results of organic carbon content in soils of paramo and wetland ecosystems in Colombia. Bogotá: Agustín Codazzi Geographic Institute, Alexander von Humboldt Biological Resources Research Institute.

by the Bouyoucos method, and applies the following equation to obtain the bulk density of the soils:

$$Bulk_D = 1.331 + 0.0001A - 0.070\,SOC \qquad \text{Equation 30}$$

Where:

$Bulk_D$ = Bulk soil density; g/cm^3

A = Sand content in the soil; percentage

SOC = Soil Organic Carbon content in the soil; percentage

From the bulk density data and using the sampled depth as a reference, the organic carbon content in the soil is determined using the following equation:

$$SOC = Bulk_D \times A \times P * \frac{SOC}{100} \qquad \text{Equation 31}$$

Where:

SOC = Soil organic carbon; kg/m^2

$Bulk_D$ = Bulk density; kg/m^3

A Mapping unit area; m^2

P = Sampling depth; m

SOC = Soil Organic carbon; percentage

Soil organic matter (SOM)

The content of soil organic matter SOM is determined by indirect methods associated, with the conversion of soil organic carbon (SOC), since this element, being its main constituent and can be determined in the laboratory.

The SOM content is determined by indirect methods associated with SOC conversion. The Soil Survey Laboratory (SSL, 1996)[70] recommends using a correction factor equal to 1.724, assuming that the organic matter contains 58% organic carbon:

The SOM is calculated using the following equation:

$$SOM = SOC \times 1.724 \qquad \text{Equation 32}$$

Where:

SOM	=	Soil organic matter expressed in percent
SOC	=	Soil organic carbon content expressed in percentage, determined by the Walkley Black method.

14.4.5 Estimation of biomass in Biodiversity-associated components

The biomass estimation (as weight and/or carbon content) for the biodiversity group suggested in section 10, is presented in Table 13.

Table 13. Estimation of biomass in biotic groups

Biotic group	**Method**
Phytoplankton	**Average cell biovolume (ACB)**: according to Mullin et al. (1966)[71], Edler (1979) and Hillebrand et al. (1999)[72]. Determined based on similarity to geometric shapes. This is conducted through photographs and using the geometric morphometry program TPSdig2 (μm^3 /ml for phytoplankton and μm3/cm^2 for phycoperiphyton).
Phycoperiphyton	**Average biovolume per individual ($AB_V I$)**: according to Strathmann (1967)[73]: ACB x average number of cells. **Average biomass per individual ($AB_M I$)**: $AB_V I$ x Density • **Biomass per sector**: $\Sigma AB_M I$ of the organisms registered in the sector.

[70]Burt, R., & Mays, M.D. (1996). Sample collection procedures for laboratory analysis in the United States soil survey program. Communications in soil science and plant analysis, 27(5-8), 1293-1298.
[71]Mullin, M. M., Sloan, P. R., & Eppley, R. W. (1996). Relationship between carbon content, cell volume, and area in phytopankton . Limnology and Oceanography, 11, 307–311.
[72]Edler, L. (ed., 1979). Recommendations for marine biological studies in the Baltic Sea. The Baltic Marine Biologist. Publication No. 38 pp.
[73]Strathmann, R. R. (1967). Estimating the organic carbon content f phytoplankton from cell volume or plasma volume1. Limnology and Oceanography, 12(3), 411–418.

Biotic group	Method
Zooplankton	**Biovolume (µm or mm depending on the species)**: according to Ruttner-Kolisko (1977) [74], using specific formulas for the geometric shapes closest to the shape of each species and following the specifications of Bottrell et al. (1976) and McCauley (1984)[75] **Biomass in wet weight (µgWW):** according to Bottrell et al. (1976) **Biomass in dry weight (µgDW):** according to Pace and Orcutt (1981) and Dumont et al. (1975)[76] **Carbon content (µgC)**: according to Rossa et al. (2007) for rotifers (48% of the DW) and according to King and Greenwood (1992) [77]for the arthropod groups (44% of the DW).
Aquatic macroinvertebrates	Using two methods, according to Wetzel and Likens (2000) [78]: **Direct by dry weight**: drying and weighing of the organisms (separated by taxon) **Indirectby length-weight relationships**: following the equations of Smock (1980)[79]

The estimation of biomass and/or carbon content are specifically proposed for the aquatic groups, with the exception of aquatic macrophytes, which are considered in the B_T and DOM compartment.

The calculation of the biomass of microscopic organisms (phytoplankton, phycoperiphyton and zooplankton), as well as macroinvertebrates, involves extensive and detailed laboratory work. Therefore, this methodology proposes a representative sample (for example, 30 individuals of each taxon) of the dominant organisms, the most abundant (per monitoring site) and the largest within each of these assemblages. The selection of dominant organisms can be done by different methods. For example, the Olmstead - Tukey test may be used (Sokal and Rohlf, 1981) [80], which considers both the abundance and frequency of organisms.

[74]Ruttner- Kolisko , A. (1977). Suggestions for biomass calculations of plankton rotifers. Archiv Für Hydrobiologie , 8, 71–76.
[75]McCauley, E. (1984). The estimation of the abundance and biomass of zooplankton in samples. In JA Downing & FH Rigler (Eds.), A manual on Methods for the Assessment of Secondary Productivity in Freshwater (pp. 228–265). Blackwell.
[76]Pace, M.L., & Orcutt, J.D. (1981). The relative importance of protozoans, rotifers, and crustaceans in a freshwater zooplankton community1. Limnology and Oceanography, 26(5), 822–830.
[77]Rossa, CD, Bonecker , C., & Fulone , L.J. (2007). Rotifer biomass in freshwater environments: review of methods and influencing factors. Interciencia , 32(4), 220–226.
[78]Wetzel, R.G., & Likens, G. (2000). Limnological analyses. Springer Science & Business Media.
[79]Biology, 10(4), 375–383.
[80]Rohlf, F.J., & Sokal, R.R. (1981). Comparing numerical taxonomic studies. Systematic Biology, 30(4), 459-490.

15 Uncertainty management

The uncertainty shall be estimated in accordance with the provisions of section 6.1 or 6.2 of the CDM methodological tool for estimating carbon stocks in trees and shrubs (as applicable)[81], as described in the following sections [82].

For biodiversity estimates, no uncertainty assessment is required.

15.1.1 Difference between two carbon stocks estimate

Change in carbon stocks is estimated as the difference between two successive, independent estimates of carbon stocks.

This method is effective when the correlation between the biomass values in the plots at the two times is either non-existent or weak (for example, when a harvest or disturbance has occurred in a stratum after the first estimate, resulting in a spatial redistribution of tree biomass in the stratum).

Using this method, the change in carbon stocks and the associated uncertainty are estimated as follows:

$$\Delta C_B = C_{B,t2} - C_{B,t1} \quad \text{Equation 33}$$

$$\mu_{\Delta C} = \frac{\sqrt{(\mu_1 \, x \, C_{B,t1})^2 + (\mu_2 \, x \, C_{B,t2})^2}}{|\Delta C_B|} \quad \text{Equation 34}$$

Where:

ΔC_B	=	Change in biomass carbon stocks during the period between two-time points t_1 and t_2; $t \, CO_{2e}$
$C_{B,t1}$	=	Biomass carbon pool at time t_1; $t \, CO_{2e}$
$C_{,t2}$	=	Tree carbon stock at time t_2; $t \, CO_{2e}$
$\mu_{\Delta C}$	=	Uncertainty in ΔC_B
μ_1, μ_2	=	Uncertainty in $C_{B,t1}$ and $C_{B,t2}$respectively

[81]Based on AR-TOOL14 Methodological tool: Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities Version 04.2
[82]The aforementioned tool is applied to biomass of trees and shrubs; for the application of this methodology it has been adapted to biomass, referring to the total biomass.

15.1.2 Direct estimation of change by remeasurement of sample plots

This method is applicable only for the ex-post estimation of the change in carbon stocks, for monitoring project activities. With this method, the same sample plots are measured on two successive occasions. The change in biomass, at the plot level, is obtained by subtracting the plot biomass in the first measurement from the plot biomass in the second measurement.

This method is effective when there is a significant correlation between the biomass values of the plots in the two measurements. For example, when there has been no harvest or disturbance in a stratum and therefore no significant spatial redistribution of biomass in the stratum has occurred after the first estimate.

With this method, the change in carbon stocks and the associated uncertainty are estimated as follows:

$$\Delta C_T = \frac{44}{12} \times FC_B \times \Delta B_B \qquad \text{Equation 35}$$

$$\Delta B_B = A \times \Delta b_B \qquad \text{Equation 36}$$

$$\Delta b_B = \sum_{i=1}^{M} w_i \times \Delta b_{B,i} \qquad \text{Equation 37}$$

$$\mu_{\Delta C} = \frac{t_{VAL} \times \sqrt{\sum_{i=1}^{M} {w_i}^2 \times \frac{s_{\Delta,i}^2}{n_i}}}{|\Delta b_B|} \qquad \text{Equation 38}$$

Where:

ΔC_T	=	Change in carbon stocks of trees, between two successive measurements; t CO_2e
CF_B	=	Biomass carbon fraction; tC(tdm)$^{-1}$ The default value is 0.47. Another value may be used if verifiable and transparent information is provided, which justifies the use of a different value.

ΔB_B	=	Changes in biomass, according to the biomass estimate for each stratum; t dm
A		Sum of the areas of the strata defined for the estimation of biomass; ha
Δb_B	=	Mean change in biomass per hectare, in estimates by stratum; t dm ha $^{-1}$
w_i		Relationship between the area of stratum i and the sum of the areas of the biomass estimation strata (i.e., $w_i = {A_i}/{A}$); dimensionless
$\Delta b_{B,i}$	=	Average change in carbon reserves per hectare, in biomass in stratum i; t dm ha $^{-1}$
$\mu_{\Delta C}$	=	Uncertainty inΔC_{ARB}
t_{VAL}	=	Student 's t value for 90% confidence level and equal degrees of freedom an - M, where n is the total number of sampling plots within the biomass estimation strata, and M is the total number of biomass estimation strata
$s^2_{\Delta,i}$	=	Variance of the average change in biomass per hectare in stratum i; (t dm ha-1) ^{2}
n_i	=	Number of sampling plots, in stratum i, in which biomass was remeasured

The mean change in biomass per hectare in a stratum and the associated variance are estimated as follows:

$$\Delta b_{B,i} = \frac{\sum_{p=1}^{n_i} \Delta b_{B,p,i}}{n_i} \qquad \text{Equation 39}$$

$$s^2_{\Delta,i} = \frac{n_i \times \sum_{p=1}^{n_i} \Delta b^2_{Bp,i} - \left(\sum_{p=1}^{n_i} \Delta b_{B,p,i}\right)^2}{n_i \times (n_i - 1)} \qquad \text{Equation 40}$$

Where:

$\Delta b_{B,i}$	=	Average change in biomass per hectare, in stratum *i*; t dm ha $^{-1}$
$\Delta b_{B,p,i}$		Change in biomass per hectare in plot p, in stratum *i*; t dm ha-1
$s^2_{\Delta,i}$	=	Variance of the average change in biomass per hectare in stratum *i*; (t dm ha-1) ^{2}
n_i	=	Number of sampling plots, in stratum *i*, in which biomass was remeasured

For the two previous cases (sections 1 5 . 1 .1 and 1 5 . 1 .2), if the estimate $\mu_{\Delta C}$is greater than 10%, it becomes a conservative estimate by applying the uncertainty discount according to the procedure provided in Table 14.

Table 14.Uncertainty discount factors

Uncertainty	Discount (% of μ)	How does it apply
μ ≤10%	0%	Estimated average = 60 ±9 t dm /ha ie μ=9/60x100 = 15% Discount=25%x9=2.25 t dm /ha Uncertainty discount: Baseline = 60 ±2.25 = 62.25 t dm /ha With project = 60-2.25=57.75 t dm /ha
10< μ ≤15	25%	
15< μ ≤20	fifty%	
20< μ ≤30	75%	
μ >30	100%	

16 Quantification of emissions reductions

16.1 Activity data

The change data in the area with natural vegetation cover (CVC) constitutes the activity data for the estimation of changes in carbon stocks.

16.1.1 Changes in natural vegetation cover (CVC)

It corresponds to changes in land use in wetland areas that change from natural vegetation cover to transformed cover in the reference period. Activity data are evaluated in the selected reference region.

To define the activity data, the project holder shall perform a land use change analysis in the reference region, following guidelines:

(a) Obtain geographic and cartographic information for the land use changes analysis. Table 15 shall be completed, listing the information used.

Table 15. Inputs for land use change analysis

Input (Vector/remote sensors)	Spatial resolution	Spectral resolution	Temporary resolution	Generation date

Input (Vector/remote sensors)	Spatial resolution	Spectral resolution	Temporary resolution	Generation date

(b) Stratify natural landcover following the guidelines in section 14.2.

(c) Generate a change detection analysis or multi-temporal analysis[83] between the period t=-5 and t=0, which allows identifying changes in land use that have occurred in the reference region. The result of this is a matrix of changes (Table 16).[84]

Table 16. Land use change matrix

Strata/Class				t2				Area (ha)
		Class$_1$	Class$_2$	Class$_3$	Class4	...	Class$_n$	
t1	Class$_1$							
	Class$_2$							
	Class$_3$							
	Class$_4$							
	...							
	Class$_n$							

[83]Supplementary information may be used to reduce the area without information. Detailed information shall be presented about the methodology, the appropriateness of the use of the selected information source and the evaluation of the accuracy of the classification.
[84]The methodology allows the use of layers available at the national level that meet the spatial and temporal resolution requirements, as input for the preparation of the matrix. The project owner shall perform an accuracy analysis of the data.

Projected change in natural vegetation cover (CVC) area in the baseline scenario for the project area.

The annual historical changes area under the baseline scenario is determined using the following equation[85]:

$$CVC_{BL} = \left(\frac{1}{t_2 - t_1}\ln\frac{A_2}{A_1}\right) * PA$$ Equation 41

Where:

CVC_{BL}	=	Change in area with natural vegetation cover in the project baseline scenario, in the reference region (ha/year)
t_2	=	year end of the reporting period in which the changes are analyzed
t_1	=	year of the reference period in which the changes are analyzed.
A_2	=	area in natural vegetation cover in the reference region in t2 (ha)
A_1	=	area in natural vegetation cover in the reference region in t1 (ha)
PA	=	eligible project area (ha)

16.2 Emission factors

To convert the amount of carbon stored in the different reservoirs to the metric unit used for comparing GHG emissions, that is (CO_{2e}), multiply the amount of carbon content in ton from the vegetation covert is multiplied by the constant (44/12).[86]

The total carbon, per stratum, is calculated with the following equation:

$$\mathrm{TC}_{Sti} = \left(\sum \mathrm{C_{BT}} + \mathrm{C_{DOM}}\right) \times \frac{44}{12}$$ Equation 42

[85]The result of the analysis of changes in natural vegetation cover will be the value used to represent the loss, expected in the baseline scenario, of biomass in natural cover.
[86] IPCC. (2006). Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Programme , Eggleston HS, Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

Where:

TC_{Sti}	=	It corresponds to the carbon content of stratum i; ton CO2
C_{BT}	=	Carbon content in total biomass; ton
C_{DOM}	=	Carbon content in dead organic matter; ton
$\frac{44}{12}$	=	Constant of the molecular ratio between carbon (C) and carbon dioxide (CO2).

To calculate the carbon stocks in each stratum, the total carbon of the stratum is multiplied per hectare (Equation 43).

$$C_{Sti} = \sum_{i=1}^{n}(TC_{St} \times A_{St}) \quad \text{Equation 43}$$

Where:

C_{Sti}	=	Carbon content in stratum i; $tCO_{2e}\ ha^{-1}$
TC_{St}	=	It corresponds to the sum of the carbon content of the deposits, of the stratum; $tCO_{2e}\ ha^{-1}$
A_{Sti}	=	Area of stratum i; ha
i	=	1, 2,3 ...n, stratum; dimensionless

For the other deposits (SOC, SOM, BIO), the biomass is also multiplied by 44/12.

16.2.1 Emissions in the baseline scenario

Emissions in the baseline scenario are estimated considering changes in wetland dynamics and changes in carbon pools in natural continental wetlands, which would occur in the absence of conservation and restoration activities.

Consequently, emissions in the baseline scenario are calculated according to Equation 44, below:

$$E_{BL} = \sum_{t=1}^{t} E_{B,BL,t} + E_{BL,Soil,t} + E_{BL,Bio} + E_{BL,Fire,t} + E_{BL,Fert,t} \quad \text{Equation 44}$$

Where:

E_{BL}	=	Emissions in the baseline scenario; tCO_{2e}
$E_{B,BL,t}$	=	Emissions due to changes in carbon stocks in biomass, in the baseline scenario, at time t; tCO_{2e}
$E_{BL,Soil,t}$	=	soil carbon stocks, in the baseline scenario, at time t; tCO_{2e}
$E_{BL,fire,t}$	=	Emissions from the combustion of woody biomass, in the baseline scenario, at time t; tCO_{2e}
$E_{BL,BIO,t}$	=	Emissions due to changes in biodiversity, in the wetland area, at time t; tCO_{2e}
$E_{BL,fert,t}$	=	Emissions from the use of fertilizers, tCO_{2e}
t	=	1, 2, 3… t, year

16.2.1.1 *Emissions from changes in carbon stocks in biomass ($B_{BL,t}$)*

Changes in biomass carbon stocks, in the baseline scenario, shall be calculated as follows:

$$\Delta CB_{BL,t} = \sum_{i=1}^{t} \Delta C_{BT,BL,t} + \Delta C_{BDOM,BL,t} \qquad \text{Equation 45}$$

Where:

$\Delta CB_{BL,t}$	=	Changes in biomass carbon stocks, in the baseline scenario, in the quantification period; t CO_2-e
$\Delta C_{BT,BL,t}$	=	Changes in carbon stocks in total biomass, in the baseline scenario, at the project limits in the quantification period; t CO_2-e
$\Delta C_{BDOM,BL,t}$	=	Changes in carbon stocks in dead organic matter, in the baseline scenario, in the project limits, in the quantification period; t CO2-e
t	=	1, 2, 3… t, year

The calculation of carbon reserves in the selected deposits in year t is carried out following the process described in section 14 .

16.2.1.2 *Emissions due to changes in soil carbon stocks ($\Delta C_{BL,Soil,t}$)*

Changes in soil carbon stocks, in the baseline scenario, shall be calculated as follows:

$$\Delta C_{BL,Soil,t} = \sum_{t=1}^{t} \Delta C_{SOC,BL,t} + \Delta C_{MOC,BL,t} \qquad \text{Equation 46}$$

Where:

$\Delta C_{BL,Soil,t}$	=	Changes in carbon stocks in the soil, in the baseline scenario, in the project limits, in the quantification period; t CO2-e
$\Delta C_{SOC,BL,t}$	=	Changes in carbon stocks in soil and sediments, in the baseline scenario, in the project limits, in the quantification period; t CO2-e
$\Delta C_{SOM,BL,t}$	=	Changes in carbon reserves in soil organic matter, in the baseline scenario, in the project limits, in the quantification period; t CO2-e
t	=	1, 2, 3… t, year

For the estimation of soil organic carbon stocks, in the baseline scenario, IPCC default values can be used.

16.2.1.3 Emissions due to changes in carbon stocks in biodiversity ($\Delta CBIO_{BL,t}$)

Changes in carbon stocks in biodiversity, in the baseline scenario, shall be calculated as follows:

$$\Delta CBIO_{BL,t} = \sum_{t=1}^{t} \Delta C_{BL,Fit,t} + \Delta C_{BL,Fic,t} + \Delta C_{BL,Zoo,t} + \Delta C_{BL,Mac,t} \qquad \text{Equation 47}$$

Where:

$\Delta CBIO_{BL,,t}$	=	Changes in biodiversity carbon reserves, in the baseline scenario, in the project limits, in the quantification period; t CO2-e
$\Delta C_{BL,fit,t}$	=	Changes in carbon reserves in phytoplankton, in the baseline scenario, in the project limits, in the quantification period; t CO2-e
$\Delta C_{BL,fic,t}$	=	Changes in carbon stocks in the phycoperiphyton, in the baseline scenario, in the project limits, in the quantification period; t CO2-e
$\Delta C_{BL,zoo,t}$	=	Changes in carbon stocks in zooplankton, in the baseline scenario, in the project limits, in the quantification period; t CO2-e
$\Delta C_{BL,mac,t}$	=	Changes in carbon stocks in aquatic macroinvertebrates, in the baseline scenario, in the project limits, in the quantification period; t CO2-e

t = 1, 2, 3… t, year

The project holder may include only some of the biodiversity components (phytoplankton, phycoperiphyton, zooplankton or aquatic macroinvertebrates).

16.2.1.4 Emissions due to the fire presence, CO2 and other GHGs ($E_{BL,Fire,t}$)

From combustion of woody biomass

If the project holder identifies the presence of fires affecting the project area, they shall quantify the emissions of CH_4 and N_2O caused by the combustion of biomass and organic soils, taking into account the guidelines presented in the IPCC guidelines of 2006 for national GHG inventories.

According to the IPCC (2019), fire is treated as a disturbance that affects not only biomass (particularly aerial biomass), but also dead organic matter (litter and dead wood); Likewise for organic soils that have been drained.

Biomass burning is the largest natural (or semi-natural) source of non-CO2 gas production. The amount released can be estimated using emission factors based on the amount of carbon released [87].

Following the IPCC guidelines, the process to estimate CO2 and Other GHG emissions is described below.

$$E_{fire\ (BT,BL} = A_{LB} \times \dot{M}_{BT} \times C_{f(BT)} \times G_{ef(BT)} \times 10^{-3}$$ [88] Equation 48

Where:

$E_{fire(BT,BL)}$	=	Greenhouse gas emissions from the total biomass fire, in the baseline scenario; tons of each GHG (CH_4, N_2O).
A_{BL}	=	Burned area in the baseline scenario; ha
M_{BT}	=	Mass of fuel available for combustion; tons ha $^{-1}$. This includes biomass, litter and dead wood[89]

[87]Pearson, T., Walker, S. & Brown, S. (2005). Sourcebook for Land use, Land-use change and forestry projects. Winrock International. 11-33 pp.

[88]The value 10-3 converts L_{fire} to tons.

[89]In accordance with IPCC guidelines, for this methodology it is assumed that litter and dead wood deposits are zero, except when there is a change in land use or there is reliable and verifiable data for the site. To know the mass of fuel available, see Modules (Biomass and MOC). For the combustion of non-woody biomass in grasslands and croplands, it is not necessary to estimate or report CO2 emissions, because it is assumed that annual CO2 absorptions (through growth) and emissions (either from decomposition or fire) by biomass are in equilibrium.

C_f = Combustion factor; dimensionless[90]
G_{ef} = Emission factor; g kg $^{-1}$ of dry matter burned[91]

CO_2 and other GHG emissions from fires in drained organic soils

Emissions of CO2 and other GHGs from the burning of drained organic soils can be measured directly or estimated using data on the area burned together with default values for mass of fuel consumed and emission factors provided by the IPCC.[92]

$$E_{fire(SOC,BL)} = A_{BL} \text{ x } \dot{M}_{B(SOC)} \text{ x } C_{f(SOC)} \text{ x } G_{ef(SOC)} \text{ x } 10^{-3}$$ [93] Equation 49

Where:

$E_{fuego(SOC)}$ = Greenhouse gas emissions from the burning of organic soils, in the baseline scenario; tons of each GHG (CH_4, N_2O).
A_{BL} = Burned area in the baseline scenario; ha
$M_{B\,(SOC)}$ = Mass of fuel (organic soil) available for combustion, tons ha $^{-1}$[94]
$C_{f(SOC)}$ organic soil combustion factor, dimensionless[95]
$G_{ef(SOC)}$ organic soil emission factor, g kg-1 dry matter burned[96]

16.2.1.5 Emissions of N_2O from the use of fertilizers ($E_{BL,Fert,t}$)[97]

$$E_{BL,fert,t} = \sum_{t=1}^{t}(F_{SN,t} + F_{ON,t}) \times FE \times \frac{44}{28} \times PCG_{N2O}$$ Equation 50

$$F_{SN,t} = N_{SN-fert,t} \times (1 - Frac_{GASF})$$ Equation 51

[90]Default values in Table 2.6; defined by the IPCC, 2019.
[91]Default values in Table 2.5; defined by the IPCC, 2019.
[92]IPCC, 2013.
[93]The value 10-3 converts L_{fire} to tons.
[94]In accordance with IPCC guidelines, for this methodology it is assumed that litter and dead wood deposits are zero, except when there is a change in land use or there is reliable and verifiable data for the site. To know the mass of fuel available, see Modules (Biomass and MOC). For non-woody biomass combustion in grasslands and croplands, CO2 emissions do not need to be estimated or reported, because annual CO2 uptakes (through growth) and emissions (either from decomposition or fire) are assumed) by biomass are in equilibrium.
[95]Default values in Table 2.6; defined by the IPCC, 2019.
[96]Default values in Table 2.5; defined by the IPCC, 2019.
[97]Equation 3.2.18, IPCC GPG LULUCF.

Where:

$E_{BL,fert,t}$	=	Direct emissions resulting from the application of fertilizers; t,tonnes CO_{2e}
$F_{SN,t}$	=	Annual amount of nitrogen fertilizer applied, tons of N, adjusted for volatilization as NH_3 and NO_x, tons of N
$F_{ON,t}$	=	Annual amount of organic fertilizer applied, adjusted for volatilization as NH_3 and NO_x, tons N
$N_{SN-fert,t}$		Amount of synthetic fertilizer applied at time t; tons of N
$N_{ON-fert,t}$		Amount of organic fertilizer applied at time t; tons of N
FE_1		Emission factor for nitrogen input emissions (tons of N/input $_{1)}$
$Frac_{GASF}$		Fraction that volatilizes with NH_3 and NO_x for synthetic fertilizers, without dimensions
$Frac_{GASM}$		Fraction that volatilizes with NH_3 and NO_x for organic fertilizers, without dimensions
PCG_{N2O}		Global warming potential for N_2O (310 for the first quantification period)

According to IPCC (2000), the default emission factor (EF_1) is 1.25% of the applied Nitrogen, and this value shall be used when there is no national factor. The default values for the synthetic and organic fertilizer fractions, which are emitted as NOx and NH3, are 0.1 and 0.2 respectively (IPCC Guidelines, 1996). Project holder can develop specific emission factors that are most appropriate for their project.

The Good Practice Guide provides guidance on how to derive specific emission factors (Section 4.1, IPCC 2000).

16.2.1.6 Emissions in the leakage area ($CVC_{LA,BL}$)

The annual historical changes in leakage area in the baseline scenario are quantified using the following equation:

$$\mathrm{CVC_{LA,BL}} = \left(\frac{1}{\mathrm{t_2} - \mathrm{t_1}} \ln \frac{LA_2}{LA_1}\right) \times \mathrm{LA} \qquad \text{Equation 52}$$

Where:

$CVC_{LA,BL}$	=	change in the area with natural vegetation cover in the baseline scenario of the leakage area, in the reference region (ha/year)
t_2	=	final year of the reference period in which the changes are analyzed

t_1	=	start year of the reference period in which the changes are analyzed
LA_2	=	surface in natural vegetation cover in the reference region of the leakage area in t2 (ha)
LA_1	=	surface in natural vegetation cover in the reference region of the leakage area in t1 (ha)
LA	=	Leakage area (ha)

The leakage, in the baseline scenario, are calculated with Equation 53.

$$E_{LA_{BL}} = \sum_{t=1}^{t} CVC_{LA_{BL,t}} \times (BT_{LA,BL,t} + DOM_{LA,BL,t}) + SOC_{LA,BL,t} + SOM_{LA,BL,t} \qquad \text{Equation 53}$$

Where:

$E_{LA_{BL}}$	=	Projected emissions the leakage area in the baseline scenario; tCO_{2e}
$CVC_{LA_{BL,t}}$	=	Projected changes in the area with natural vegetation cover in the leak area, baseline, (ha/year)
$BT_{LA,BL,t}$	=	Changes in biomass carbon stocks in the baseline scenario, at time t; tCO_{2e}
$DOM_{LA,BL,t}$		Emissions in dead organic matter reserves in the baseline scenario, at time t; t CO2e
$SOC_{LA,BL,t}$	=	Emissions in soil carbon stocks in the baseline scenario, at time t; t CO2e
$SOM_{LA,BL,t}$	=	Emissions in soil organic matter reserves, in the baseline scenario, at time t; t CO2e
t	=	1, 2, 3… t, year

16.2.2 Estimation of emissions reduction in the project scenario (ER_P)

The reduction in emissions due to avoiding changes in land use, in the project scenario, is estimated according to the equation:

$$ER_P = (t_2 - t_1) * (E_{BL} - E_P - E_{LA}) \qquad \text{Equation 54}$$

Where:

ER_P	=	Emission Reduction of project; tCO_{2e}
E_{BL}	=	Emissions in the baseline scenario; $tCO_2e\ year^{-1}$

E_P	=	Emissions in the project scenario; $tCO_2e\ year^{-1}$
E_{LA}	=	Emissions in the leakage area; $tCO_2e\ year^{-1}$
t2		Final year of the period in which the changes are analyzed
t1		Initial year of the period in which the changes are analyzed

16.2.2.1 Emissions in the baseline scenario (E_{BL})

Emissions that would be generated in the baseline scenario due to changes in land use in continental natural wetland areas. GHG emissions are estimated considering the areas in the scenario without the project and the carbon content that would be emitted into the atmosphere if said areas are transformed (Equation 55).

$$E_{BL} = \sum_{t=1}^{t} CVC_{BL,t} \times (BT_{BL,t} + BDOM_{BL,t}) + \left(SOC_{BL,t} + SOM_{BL,t}\right) \times A_p + \left(BIO_{BL,t}\right) \times A_{wm} + (E_{fire,BL,t}) \times A_{fire,BL,t} + (E_{Bl,fert,t})$$

Equation 55

Where:

E_{BL}	=	Project emissions in the baseline scenario; $tCO_2e\ ha^{-1}$
$CVC_{BL,t}$	=	Projected change in the area with natural vegetation cover in the project's baseline scenario, in the reference region; $ha\ year^{-1}$
$BT_{BL,t}$	=	Carbon content in total biomass in the baseline scenario; $tCO_2e\ ha^{-1}$
$BDOM_{BL,t}$	=	Carbon content in the dead organic matter in the baseline scenario, in stratum i; $tCO_2e\ ha^{-1}$
$SOC_{BL,t}$	=	Soil carbon content in the baseline scenario; $t\ CO_2e\ ha^{-1}$
$SOM_{BL,t}$	=	Carbon content in soil organic matter, in the baseline scenario; $tCO_2e\ ha\text{-}^1$
$E_{fire,BL,t}$	=	GHG emissions from carbon combustion in the baseline scenario; $tCO_2e\ ha^{-1}$
$E_{Bl,fert,t}$	=	Emissions from the use of nitrogen fertilizers; $tCO_2e\ ha^{-1}$
A_p	=	Project area; ha
A_{wm}	=	Water mirror area; ha
$A_{fire,BL,t}$	=	Area with presence of fires, in the baseline scenario; ha
t	=	1, 2, 3... t, year

16.2.2.2 Emissions in the project scenario (E_P)

Project area

Emissions in the scenario with project are calculated according to Equation 56, below:

$$E_{p,t} = \sum_{t=1}^{t} CVC_{p,t} \times (BT_{p,t} + BDOM_{p,t}) + (SOC_{p,t} + SOM_{p,t}) \times A_p + (BIO_{p,t}) \times A_{wm} + (E_{fire,p,t}) \times A_{fire,p,t} + E_{p,fert,t} \quad \text{Equation 56}$$

Where:

$E_{P,i,t}$	=	Emissions in the project scenario; tCO_{2e}
CVC_P	=	change in the surface with natural vegetation cover in the scenario with project, (ha/year)
$BT_{P,t}$	=	Changes in carbon stocks in total biomass in the project scenario, in stratum i, at time t; tCO_{2e}
$SOC_{P,t}$	=	Emissions in soil carbon stocks in the scenario with the project, at time t; t CO_2e
$SOM_{P,t}$		Emissions in carbon stocks in soil organic matter in the scenario with the project, at time t; t CO_2e
$BDOM_{P,t}$		Emissions in the reserves of dead organic matter in the scenario with the project, at time t; t CO_2e
$BIO_{p,,t}$		Emissions in carbon reserves in biodiversity, in the scenario with project, at time t; t CO_2e
$E_{fire,p,t}$		Greenhouse gas emissions from the fire, in scenario with project, at time t; t CO_2e
$E_{p,fert,t}$		Greenhouse gas emissions generated by the application of synthetic nitrogen fertilizers; at time t; tCO_2e
A_p		Project area; ha
A_{wm}		Water mirror area; ha
$A_{fire,p,t}$		Area with presence of fires, in the scenario with base project; ha
t	=	1, 2, 3… t, year

Projected changes in natural vegetation cover (CVC_P) area in the project scenario, in the project area

GHG emissions in the project area, in the scenario with the project, are quantified using the following equation:

$$CVC_P = CVC_{BL} * (1 - \%DC_P) \quad \text{Equation 57}$$

Where:

CVC_P	=	change in the surface with natural vegetation cover in the scenario with project, (ha/year)
CVC_{BL}	=	change in the area with natural vegetation cover in the baseline scenario (ha/year)
$\%DC_P$	=	percentage of projected decrease in coverage changes due to implementation of project activities

16.2.2.3 Leakage area

$$E_{LA} = \sum_{t=1}^{t} CVC_{LAp} \times (BT_{LA,t} + BDOM_{LA,t}) \quad \text{Equation 58}$$

Where:

E_{LA}	=	Emissions the leakage area in the project scenario; tCO_{2e}
CVC_{LAp}	=	Change in the surface with natural vegetation cover in the leakage area, scenario with project, (ha/year)
$BT_{LA,t}$	=	Changes in carbon stocks in total biomass in the project scenario, in stratum i, at time t; tCO_{2e}
$BDOM_{LA,t}$	=	Emissions in dead organic matter reserves in the baseline scenario, at time t; t CO2e
t	=	1, 2, 3... t, year

Projected changes in the area with natural vegetation cover (CVC) in the scenario with project, in the leakage area

GHG emissions in the leak area, in the project scenario, are quantified using the following equation:

$$CVC_{LA-P} = CVC_{LA_{BL}} * (1 + \%ICC_{LA}) \quad \text{Equation 59}$$

Where:

CVC_{LA-P}	=	change in the surface with natural vegetation cover in the leak area, scenario with project, (ha/year)
$CVC_{LA_{BL}}$	=	change in the area with natural vegetation cover in the baseline scenario (ha/year)
$\%ICC_{LA}$	=	percentage of increase in coverage changes due to the implementation of project activities.

16.2.2.4 Quantification of the emissions reduction generated by the implementation of conservation activities

The GHG project reductions shall be calculated as follows:

$$\Delta C_{p,t} = \Delta C_{p,BL,t} - \Delta C_{p,ACTUAL,t} - LA_{p,t} \quad \text{Equation 60}$$

Where:

$\Delta C_{p,t}$	=	Net GHG reductions from conservation activities, in year *t;* t CO_{2-e}
$\Delta C_{ACTUAL,t}$	=	GHG reductions from conservation activities, in year *t;* t CO_2-e
$\Delta C_{BL,t}$	=	GHG emissions in the baseline, in year *t;* t CO_2-e
$LA_{p,t}$	=	GHG emissions due to leakage from conservation activities, in year t; t CO_2-e

16.2.2.5 Estimation of the results of reduction and removal of project activities

The GHG project results shall be calculated as follows:

$$\Delta C_{PROJECT,t} = \Delta C_{R,t} + \Delta C_{CON,t} \quad \text{Equation 61}$$

Where:

$\Delta C_{PROJECT,t}$	=	Net GHG reductions from conservation activities, in year *t* ; t CO_{2-e}
$\Delta C_{R,t}$	=	Net GHG removals by reservoirs, due to restoration activities, year *t;* tCO_{2-e}
$\Delta C_{CON,t}$	=	Net GHG reductions from conservation activities, in year *t* ; t CO_{2-e}
t	=	1, 2, 3… t, year

17 Monitoring plan

The project holders shall present a monitoring plan in accordance with what is established by the standard and shall additionally describe the procedures to monitor project activities and the reduction of GHG emissions, within the scope of the project.

The GHG Project holder shall demonstrate that emissions or removal reductions are quantified, monitored, reported and verified, through the application of the BCR Tool "Monitoring, reporting and verification (MRV)"

Document History

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