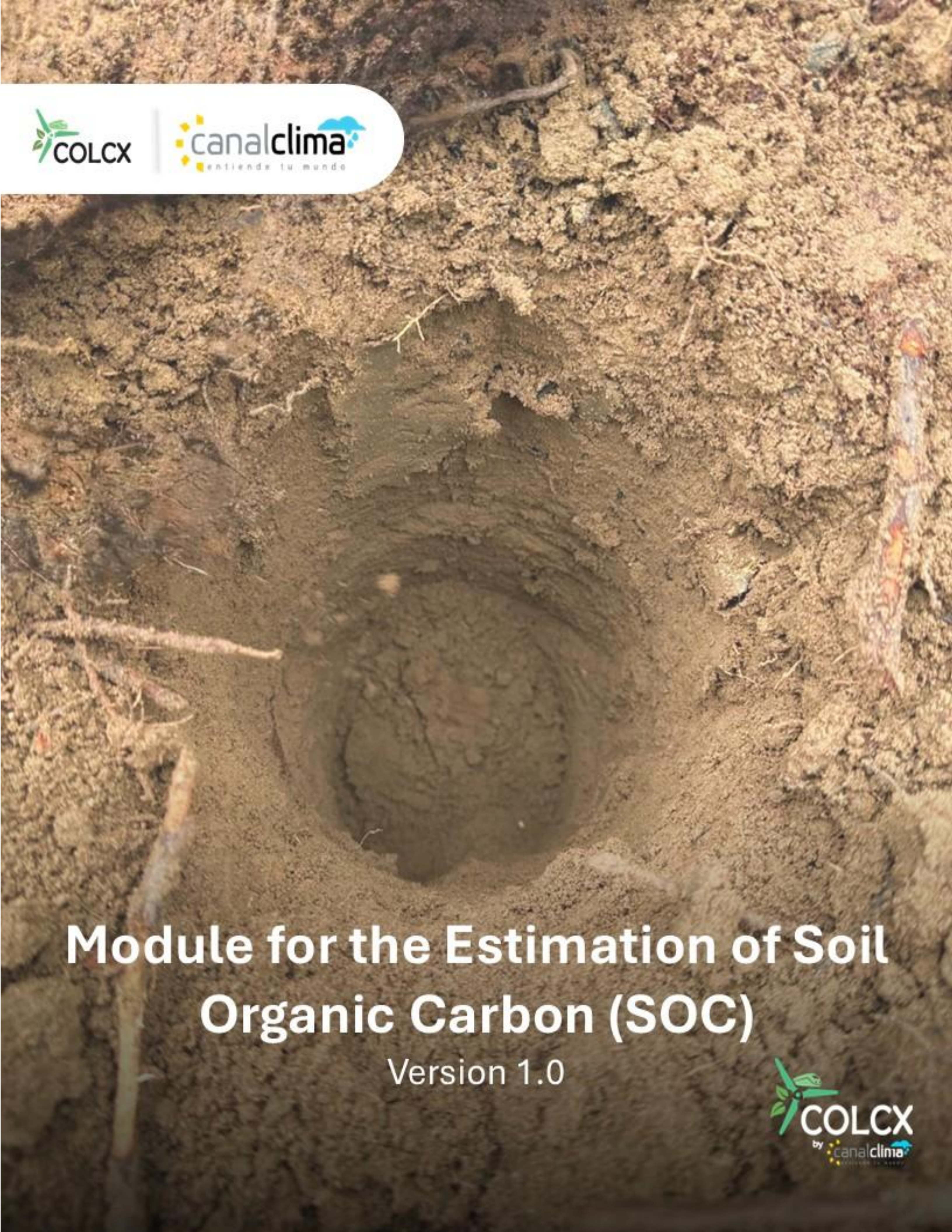

Module for the Estimation of Soil Organic Carbon (SOC)

Version 1.0

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Terms and Definitions

Soil Pit (Calicata): A vertical excavation in the soil, generally 1 to 2 meters deep, carried out for the purpose of observing, describing, and sampling the soil profile. It allows the identification of horizons, assessment of physical and chemical characteristics, and the collection of samples for soil analysis of different types.

Soil Organic Carbon (SOC): The fraction of carbon contained within soil organic matter, which can be expressed as a percentage and/or as a unit of mass.

Fraction-Specific Bulk Density : The bulk density of different soil fractions, relating to the specific volume they occupy within the sample. It is expressed in g/cm^3 or Mg/m^3.

Stratification: The distribution and grouping of soil into homogeneous units according to distinct physical, chemical, biological, or geographic characteristics that suggest similarity and reduce result variability.

Fine Fraction: Soil particles smaller than 2 mm. This fraction is used to analyze organic carbon content, texture, pH, among others. It does not include stones, gravel, or large plant residues.

Coarse Fraction: Soil particles larger than 2 mm, including gravel, stones, roots, or large plant residues. It is not considered in the direct SOC analysis but must be quantified to correctly calculate total volume and adjust bulk density.

Organic Fraction: Soil components derived from organic matter at different stages of decomposition, such as plant residues, roots, microorganisms, and humus; it may also be referred to as SOM (Soil Organic Matter).

Quantification Method: A process designed to determine specific data (magnitudes) that enables the estimation of SOC changes, whether through direct measurement, modeling, or a combination of both.

Soil: The upper layer of the Earth's crust is composed of minerals, organic matter, water, air, and living organisms; resulting from the weathering of minerals and rocks and the accumulation of organic materials.

SOC Stock: The total amount of organic carbon stored in the soil per unit area and at a specified depth.

In addition to the definitions mentioned above, the GHG Management Plan (PMGEI) must consider the most updated version of the COLCX Program's Guide to Terms and Definitions.

1 INTRODUCTION

Climate change is a global phenomenon that has affected humanity and its livelihoods, as well as the stability of value chains. The magnitude of this impact has driven the search for alternatives to mitigate GHG emissions and adapt to their effects. Within this context, projects have been developed focusing on the reduction and removal of GHG emissions across multiple sectors, including industry, manufacturing, and energy, with significant potential in soils and their agricultural, forestry, and livestock uses.

Soil represents one of the largest carbon reservoirs in the terrestrial system. It is estimated to contain more than 3 trillion metric tons of organic carbon within the first two meters of depth[1], up to four times more than that sequestered by biomass and three times more than atmospheric carbon[2], ven exceeding the combined carbon stored in vegetation and the atmosphere[3]; This makes soil one of the world's primary carbon reservoirs. Consequently, any change in reservoirs of this type can translate into significant alterations in atmospheric CO_2 concentrations and may therefore act as either an accelerator or a mitigator of climate change[4].

Within soils, the proportions of sequestered carbon are determined by their specific properties, including microbial activity, the amount of organic residues incorporated into the soil matrix, leaching processes, among others. Additionally, these carbon contents are subject to changes in management practices and land use associated with various productive activities, enabling soil to function either as a source or as a sink of GHGs (CO_2, N_2O, CH_4).

Recognizing the importance of soil as both a carbon emitter and receiver, COLCX has developed this module as a tool for quantifying soil organic carbon, enabling its inclusion within the program's mitigation initiatives. This module serves as a complementary instrument to COLCX methodologies, which promote rigor in the quantification and monitoring of carbon stored in different reservoirs, supported by biophysical factors, intervention objectives, and field limitations.

[1] Kopittke, P. M. et al..(2024). 1 Petagram = 1 billon
[2] Lal,R. (2004)
[3]Martínez H, Eduardo, et al.. (2008).
[4] Lal, R et al.. (2021)

2 SCOPE

This module is intended for project owners and proponents implementing sustainable soil management and land-use activities within the framework of GHG mitigation initiatives and quantifying carbon stocks in project soils.

Likewise, this module applies to initiatives reporting results under COLCX methodologies in forestry and agricultural activities, provided they fully comply with both the requirements of the applicable methodology and those established in this module[5].

3 APPLICABLE ACTIVITIES

This module applies to all mitigation initiatives that, within the reservoirs defined in both the baseline and project scenarios, include Soil Organic Carbon (SOC).

Only removals stored in this reservoir shall be quantified. That is, emission reductions generated through good agricultural practices—such as reduced fertilizer use or similar measures—may not be reported under this module. However, they may be accounted for within the total emission flows of the project, as defined by the methodology adopted by the GHG Management Plan (PMGEI).

Applicable Activities:

- Soil conservation mechanisms in forestry practices and forest areas: terracing, conservation of erosion-prone soils, and runoff control.
- Implementation of agroforestry and afforestation practices that improve conditions in areas with degraded soils.
- Control of grazing dynamics through rotational management and regulation of pasture use intensity.
- Organic matter management for soil restoration. [6]
- No-tillage practices and/or crop residue management.

Non-Applicable Activities:

- Manipulation of peatlands or organic soils.
- Continuation of conventional practices that do not contribute to increased removals.
- Passive conservation of natural areas that do not present disturbances or impacts to soil structure.
- Quantification of changes in areas where no activities have been carried out and baseline conditions are maintained. That is, changes (losses or gains) in the

[5] In the event of overlapping or conflicting terminology, the methodology shall prevail over this tool.
[6] The organic content of the product may not be used as the final result for SOC quantification within the soil profile.

reservoir result from the ecosystem's natural dynamics rather than from project activities.

Likewise, the specific applicability conditions for each initiative shall also be defined in the corresponding methodologies, complemented by the provisions set forth in this document.

4 ELIGIBILITY

The eligibility conditions for areas where the SOC quantification module is applicable are defined below.

4.1 Eligible Areas

All areas defined as eligible within the eligibility chapters of the AFOLU sector methodologies of COLCX shall be considered eligible, including:

- *Methodology for Greenhouse Gas Removal in Forest Plantations, Agroforestry Systems, and Agricultural Activities.*
- *COLCX Methodology for Pasture and Soil Management.*
- *COLCX Methodology for REDD+ Projects.*

Any other methodologies developed by COLCX for activities within the sector, in their most recent version.

4.2 Non-Eligible Areas

All areas identified as excluded in the methodology applicable to the initiative shall be considered non-eligible. For this purpose, the provisions established in the AFOLU sector methodologies of COLCX must be taken into account, including:

- *Methodology for Greenhouse Gas Removal in Forest Plantations, Agroforestry Systems, and Agricultural Activities.*
- *COLCX Methodology for Pasture and Soil Management.*
- *COLCX Methodology for REDD+ Projects.*

Any other sectoral methodologies developed by COLCX, in their most recent version.

Additionally, for the purposes of quantification under this module, the following areas are not considered eligible, as they correspond to ecosystems with special conditions (moisture and anoxia), particular carbon cycle dynamics, and high sensitivity to degradation resulting from activities and interventions:

- Areas defined as peatlands or areas within the same ecosystem that have been drained or modified by agricultural or livestock practices.
- Natural or artificial wetlands are located within the project area.
- Organic soils classified as Histosols within the project area. This classification may be based on official soil cartography of the host country or on the

determination of physicochemical properties; for example, very high contents of decomposing organic matter (advanced mineralization processes), saturated or partially saturated moisture conditions, muddy (or peat) soils with humic substance formation[7], and/or typically low bulk densities below 1 g/cm^3 (commonly ranging between 0.1 and 0.2 g/cm^3)[8].

These areas may only be considered eligible for SOC quantification when the objective of the mitigation initiative and its activities is the restoration of these ecosystems (e.g., rewetting, protection, and/or preservation), under specific parameters defined for such areas within the applicable methodologies, and in compliance with host country guidelines.

5 TEMPORAL AND SPATIAL BOUNDARIES

The establishment of temporal and spatial boundaries enables clear and precise quantification of Soil Organic Carbon (SOC) for initiatives, ensuring technical consistency and information traceability for the quantification of total emission reductions or removals.

5.1 Temporal Boundaries

Specific guidelines are set forth in the methodology applicable to the initiative, as well as in the relevant program and certification standard. In all cases, SOC shall have the same time horizon as the initiative reporting it, or until the reservoir stabilizes.

Temporal boundaries must be defined and established during the structuring of the GHG Management Plan (PMGEI) and reported in the submitted documentation (Project Design Document – PDD, Monitoring Report – MR, among others).

5.2 Spatial Boundaries

The spatial boundaries of the project must be defined during the structuring of the GHG Management Plan (PMGEI) and reported in the documentation prepared by the initiative (PDD, MR, among others). Specific guidelines for their definition shall be those established in the methodology applicable to the initiative, as well as in the relevant program and certification standard.

[7] FAO. (2007). IUSS Grupo de Trabajo WRB. 2007. Base Referencial Mundial del Recurso Suelo. Primera actualización 2007. Informes sobre Recursos Mundiales de Suelos No. 103. FAO, Roma.

[8] Corporación Autónoma Regional de Cundinamarca – CAR (2017.). DIAGNÓSTICO Y MONITOREO DE DEGRADACIÓN DE SUELOS POR SALINIZACIÓN EN EL DMI COMPLEJO LAGUNAR FÚQUENE, CUCUNUBA Y PALACIOS, JURISDICCION CAR A ESCALA 1:25.000

6 SOIL ORGANIC CARBON (SOC) QUANTIFICATION

This chapter provides guidance for quantifying changes in SOC stocks and defines the possible quantification methods accepted under this module:

1. Direct sampling – direct measurement.
2. Carbon stock modeling.
3. Analytical methods for SOC estimation based on the determination of Soil Organic Matter (SOM).
4. Application of default factors defined by the Intergovernmental Panel on Climate Change or reported in peer-reviewed scientific research.

6.1 SOC Quantification Methods

The proposed methods are based on the "*Protocol for National and Subnational Biomass-Carbon Estimation in Colombia*[9]",, as well as on technically and scientifically validated estimation and modeling methods, or through the use of default factors. The estimation and quantification of organic carbon for ex-ante projections and ex-post quantification shall be carried out using any of these methods (according to the proponent's selection), as applicable.

6.1.1 Direct Sampling

To determine changes in carbon stocks using this method, sampling units must be established within the project area. These sampling units must represent the dynamics of carbon stocks under the project scenario.

Monitoring of the sampling units will allow for the determination and updating of soil organic carbon stock values under the project scenario during the different monitoring events conducted by the PMGEI.

A PMGEI implementing this quantification method must comply with the following procedure:

Step 1. Stratification and Sampling Design

Variables or criteria to be included in the stratification process must be defined in order to establish homogeneous sampling areas, aiming to reduce uncertainty and increase the precision of estimated stored carbon values (Pearson et al., 2005). The variables to be considered in the stratification process may include:

- **Soil Type:** Define the soil types present within the project area, since each soil type (clay, sandy, silty) has different carbon sequestration capacities (FAO, 2018).

[9] Yepes et al., IDEAM, 2011

- **Vegetation cover:** Identify cover types such as forested areas, agricultural lands, or pastures, consistent with the classification carried out in the initiative design and in accordance with the methodology governing the initiative.
- **Historical land use:** Delineate areas with a history of forestry, agricultural, or livestock practices over a period exceeding five years prior to project start, as land-use dynamics may have conditioned carbon stocks.
- **Slope:** Define classes according to the topographic units present in the project area, since SOC accumulation varies with slope level; areas with steep slopes may be more susceptible to erosion, affecting carbon retention (Lal, 2004; Madrigal Reyes et al., 2019).

Subsequently, soils shall be grouped into homogeneous units according to the defined stratification criteria or variables for sampling, or, where applicable, in consistency with prior stratifications conducted by the PMGEI.

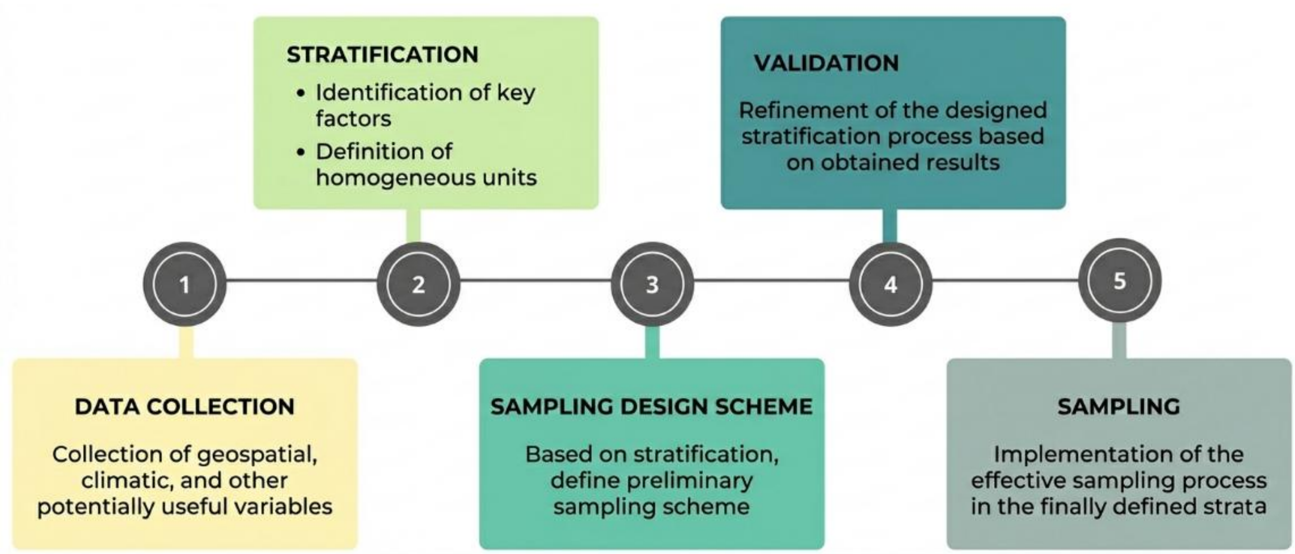

Illustration 1. Project Area Stratification Process.

Sampling Desing: A sampling plan must be established[10], covering the different defined strata, which may or may not be associated with previous stratifications carried out under the PMGEI, but in all cases based on sound technical criteria.

[10] Different sampling methods may be selected, provided that they comply with the valid statistical parameters established by the applicable methodology.

The sampling approach used must ensure a sampling error no greater than 10% of the mean carbon value, at a 95% confidence level[11]. Finally, a field validation of the stratification exercise must be conducted to verify its accuracy and applicability.

Step 2. Soil Sampling

Sample Collection: The PMGEI must define the number of samples and/or subsamples[12] (in the case of composite samples), considering different depth intervals, commonly 0-10 cm, 10-20 cm, 20-50 cm, or others as determined by the PMGEI.

Sampling must include collection to a minimum depth of 30 cm, while seeking to reach the greatest feasible depth to increase certainty regarding SOC contents throughout the soil profile (see Figure 1).

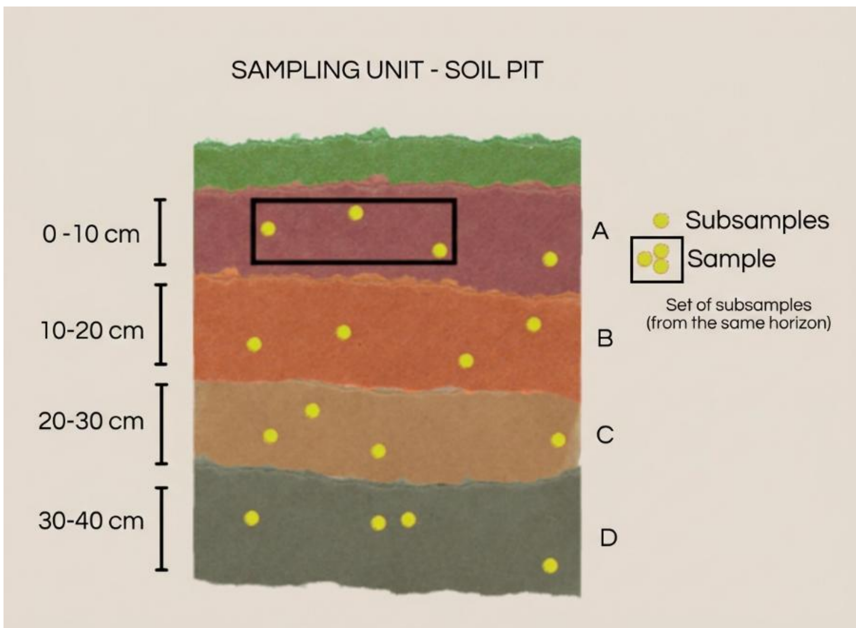

Figure 1. Diagram of Sample Extraction Within the Sampling Unit.

It is recommended to collect samples by excavating soil pits measuring 1 m × 1 m × 1 m (1 m^3) to enable sampling at the selected depths. At this stage, it is advisable to collect samples using cylinders with a defined volume and a diameter of 5 to 10 cm, which facilitates the subsequent calculation of bulk density, or by using another method that allows for a clear and precise determination of the collected volume.

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[11] To determine the number of sampling units, it is recommended to use the tool "Calculation of the number of sample plots for measurements within A/R CDM project activities", developed under the United Nations Framework Convention on Climate Change (UNFCCC) framework. Available: https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-03-v2.1.0.pdf

[12] Samples shall be extracted from the sampling unit (soil pit), and subsamples may consist of multiple collections taken within the same horizon, which may be combined to form a single composite sample.

Each sample must include the geographic coordinates of the point where it was collected.

Preservation and Transport: Soil samples must be properly preserved to prevent moisture loss and other changes that could alter the physical and chemical parameters to be evaluated.

Step 3. Laboratory Analysis

The purpose of this step is to determine soil organic matter (SOM) and subsequently convert it to equivalent carbon content. The PMGEI must ensure and provide evidence that soil sample analyses are conducted in a laboratory meeting the following requirements:

- Accreditation by nationally or internationally recognized entities certifying the quality of analytical processes and techniques, in accordance with ISO 17025 (standard specifying general requirements for the competence of testing and calibration laboratories, ensuring technical competence and reliability of results).
- Availability of specific equipment for soil organic carbon analysis, such as Total Organic Carbon (TOC) analyzers or dry combustion equipment.
- Rigorous quality control protocols, including the use of reference samples, duplicates, and blank controls.

The determination of organic carbon (OC) content will depend on the selected analytical method:

- Dry combustion method: The most accurate method for SOC determination. However, it presents limitations in calcareous soils due to potential difficulty distinguishing between organic and inorganic carbon (Apesteguia et al., 2018), and it requires specialized materials and equipment, increasing costs (Dos Santos et al., 2008).
- Wet combustion method (Walkley–Black, 1934): Commonly the most widely used method. However, it is estimated to recover only 75% to 85% of the OC determined by dry combustion, typically underestimating OC content. Therefore, correction factors are generally required depending on soil type (Apesteguia et al., 2018).
- Other methods: Spectrophotometry- or thermogravimetry-based methods may serve as alternative approaches. These may be faster and less invasive in nature, but require sufficient calibration to ensure accurate results.

Step 4. SOC Quantification

The quantification of soil organic carbon is determined by the proportion of carbon contained in the soil at a given depth, adjusted based on information regarding volumes and densities of organic matter, fine and coarse fractions, rocks, and other sample components. Part of this information is obtained through laboratory analysis.

Calculation of Coarse Fraction Volume

The equations for calculating sample volume and density must be applied at each sampled depth within the same soil pit, following the protocol established by Burton & Pregitzer (2008), as cited by Yepes et al. (2011).

The volume of rocks (coarse fraction) is calculated as follows:

Equation 1. Calculation of Coarse Fraction Volume

$$V_{fg} = \frac{M_R}{D_R}$$

Where:

V_{fg} = *Volume of rocks or coarse fraction (cm³)*
M_R = *Mass of rocks (g) (includes rocks and soil fraction > 2 mm)*
D_R =*Density of rocks or coarse fraction (g/cm³) (This density must be determined using the water displacement method)*[13]

Calculation of Volume and Bulk Density of the Organic Fraction

To calculate the specific bulk density of the sample, it is necessary to determine both the volume occupied and the mass of the organic fraction. The volume of coarse roots (roots > 2 mm in diameter) is calculated as follows:

Equation 2. Calculation of Coarse Root Volume

$$V_{fo} = \pi \times r^2 \times l$$

Where:

V_{fo} = *Volume of the organic fraction, i.e., coarse roots (cm³)*
π = *Pi constant (dimensionless)*
r = *Root radius (cm)*
l = *Root length (cm)*

[13] This method consists of placing the rocks inside a graduated cylinder (e.g., a volumetric cylinder) and determining the volume of water displaced when the rocks are submerged. If it is not possible to determine it using this method, the density of a given material must be assumed, which in this case will depend on the type of rock.

Equation 3. Calculation of Bulk Density of the Organic Fraction.

$$D_{om} = \frac{M_{om}}{V_{fo}}$$

Where:

D_{om} = Bulk density of the soil organic fraction (g/cm³)
Mom = Total dry mass of coarse roots and other organic materials (g) (includes roots and excludes pieces of dead wood).
V_{fo} = Volume of the organic fraction, i.e., coarse roots (cm³) (this volume includes all materials mentioned inM_{om}) (cm³)

Calculation of Volume and Bulk Density of the Fine Fraction

The volume of the fine fraction—defined as the material passing through a 2 mm sieve, as well as organic material excluding coarse roots—is calculated as follows:

Equation 4. Calculation of Fine Fraction Volume

$$V_{ff} = V_T - V_{fg} - V_{fo}$$

Where:

V_{Ff} = Volume of fine fractions (cm³)
V_T = Total volume (cm³), i.e., the volume of the sampling cylinder
V_{fg} = Volume of rocks (cm³)
V_{fo} = Volume of coarse roots (cm³)

The bulk density of the fine fractions is calculated as follows:

Equation 5. Calculation of Bulk Density of Fine Fractions

$$D_F = \frac{M_{ff}}{V_{ff}}$$

Where:

D_F = Bulk density of fine fractions (g/cm³)
M_{ff}= Total dry mass of fine fractions (g)
V_{ff} = Volume of fine fractions (cm³)

If coarse roots are not present, the bulk density of the fine fraction may be calculated by subtracting only the volume of the coarse fraction.

If the sample does not contain coarse fraction (rocks > 2 mm) or coarse roots, the calculation steps for coarse fraction and organic fraction volumes (Equations 1 to 4) may be omitted. In such cases, the bulk density of the fine fraction will correspond to the bulk density of the entire sample, determined based on the total volume of the extraction cylinder used or the known sample volume.

Calculation of SOC Content in the Sample

To calculate total soil carbon stocks from the analyzed samples, the different material fractions present at each sampled depth must be considered. This includes the carbon concentration in the fine soil fraction, in organic material, in coarse roots, and the total analyzed sample volume, in order to obtain the total stored carbon value.

All calculations are performed using the following formula:

Equation 6. Calculation of Carbon Stocks for a Given Depth Including the Organic Fraction

$$RC_p = E \times \left(10000\frac{cm^2}{m^2}\right) \times \left(\left(\left(\frac{Cff}{1000}\right) \times D_F\right) + \left(\left(\frac{Com}{1000}\right) \times D_{om}\right)\right)$$

Where:

RCp = Carbon stock (gC/m²), i.e., the total amount of carbon stored at each sampled depth.
E = Thickness of the sampled horizon (cm).
C_{Ff} = Carbon concentration in the fine soil fractions (gC/kg), i.e., the carbon present in materials passing through a 2 mm sieve. (Data provided by the laboratory.) (If the concentration is given in %, it should not be divided by 1000.)
D_F = Bulk density of the fine fractions (g/cm³).
C_{OM} = Carbon concentration in organic material with a diameter greater than 2 mm (gC/kg).
D_{om} = Bulk density of the soil organic fraction (g/cm³).
10000 = Area unit conversion factor from cm² to m² to standardize the equation units.

This process must be carried out for each sampled depth within the soil pit. In this way, carbon stocks can be calculated for different soil layers, providing a more precise estimate of the carbon content throughout the entire soil profile of the plot or soil pit. The resulting values must be extrapolated to tons per hectare (t/ha).

Equation 7. Calculation of Carbon Stocks per Plot or Sampling Unit.

$$\mathrm{ROS}_{t=i} = (\left(\frac{\left((\sum_{i=n}^{np} RC_{pi})\right)}{1000000}\right) \times \frac{10000}{AM})$$

$ROS_{t=i}$ = Carbon stock (tC/ha) per sampling unit (soil pit) for stratum i.
RC_{pi} = Carbon stock (gC/m²) for depth p, in stratum i, per plot.
np = Total number of sampled depths in the plot.
AM = Area of the sampling unit (m²).
1000000 = *Conversion factor from grams to tonnes.*
10000 = *Conversion factor from m² to hectares.*

For each established plot, this calculation is iterated to determine the average carbon stock (tC/ha) for that plot, which is then extrapolated to the total surface area of the stratum (tC/stratum).

Equation 8. Calculation of Average Carbon Stocks for Stratum i

$$\mathrm{ROSE}_i = \left(\frac{\left((\sum_{i=n}^{npe} \mathrm{ROS}_{t=i})\right)}{n}\right) \times A_i)$$

Donde

$ROSE_i$ = Average carbon stock (tC) for the entire stratum i in the project.
$ROS_{t=i}$ = Carbon stock per plot or sampling unit (tC/ha) (soil pit) for stratum i.
n = Total number of sampling units per stratum.
A_i = Area of stratum i (ha).

If quantification has been performed for multiple strata, the carbon stocks of each stratum must be summed to obtain the total carbon stock for the entire project area in year *t*.

Equation 9. Total Equivalent Carbon Dioxide Present in the Project in Soil Organic Carbon at Time t = i

$$P\mathrm{COS}_{t=i} = \left(\sum_{i=n}^{N} \mathrm{ROSE}_{t=i}\right) \times \frac{44}{12}$$

Where:

$PCOS_{t=i}r$ = Soil organic carbon for the project at time t = i, expressed in CO_2 equivalent (tCO_2e).
$ROSE_{t=i}$ = Average carbon stock of stratum i (tC).
N = Total number of strata.

$\frac{44}{12}$ = *Molecular weight ratio of CO_2 to C (dimensionless).*

6.1.2 Soil Carbon Stock

This method involves developing and/or using models to quantify soil carbon stocks, incorporating information on soil types and projected carbon contents within the spatial limits defined by the PMGEI. These models must consider factors such as geographic conditions, soil units, physical and/or chemical characteristics, and other edaphic and climatic aspects that influence carbon accumulation.

Data used to develop these models must come directly from the spatial boundaries defined by the PMGEI, ensuring predictions are accurate and consistent with local soil and ecosystem dynamics.

Once developed, the model must include detailed documentation and justification of the data used, explaining data sources, collection methods, and representativeness.

Proponents may use pre-existing models or develop their own, provided they meet the following rigor and representativeness criteria, and are validated by third-party verification:

1. The model must demonstrate, at a minimum, the following statistical metrics to assess its precision and consistency:
   - Coefficient of Determination (R^2): The model must achieve an R^2 value greater than 0.85, indicating that it explains at least 85% of the variability in the data.
   - Root Mean Square Error (RMSE): The RMSE must be sufficiently low to ensure minimal deviation between predicted and observed values.
2. A cross-validation process must be conducted, using at least 10% of the data for testing (field data), ensuring that the model is not overfitted.
3. The model must demonstrate stability in its results when applied to data from different periods or to different datasets continuously.
4. Model residuals (the differences between predicted and observed values) must exhibit a random distribution without systematic patterns, demonstrating that the model is unbiased.
5. The model must be tested under different input conditions to evaluate its robustness and responsiveness to variations in the data.

Widely recognized models such as **RothC** or **SOCrates** can be employed. These models use area-specific variables to quantify changes in soil carbon stocks according to processes of mineralization and transformation of soil fractions.

6.1.3 Analytical Methods for SOC Estimation

These methods include thermogravimetric techniques, in which the organic and inorganic fractions of the soil are quantified through controlled or continuous combustion. This allows for the subsequent determination of SOC (Soil Organic Carbon) and SIC (Soil Inorganic Carbon). These methods are based on the differences in organic and inorganic content during exothermic and endothermic reactions that occur during decomposition when subjected to calcination processes (Apesteguia, M et al., 2018).

These SOC estimation methods are permitted by the IPCC at Tier 2 and Tier 3 levels and are accepted as indirect methods for SOC estimation. However, they may underestimate or overestimate carbon content, since weight loss can be influenced by multiple factors and is not solely due to the combustion of organic matter.

6.1.3.1 Loss-on-Ignition (LOI) Method

This method involves determing the organic matter or organic fraction of the soil based on the weight loss of a sample after a calcination[14] process (Barrezueta-Unda, S. et al., 2020).

Several soil samples are selected according to the stratification carried out. Different sample weights should also be chosen. After an initial drying at approximately 105°C, the samples are subjected to calcination at temperatures above 220°C and commonly below 600°C (Barrezueta-Unda, S. et al., 2020; Izquierdo, J. & Arévalo, J., 2021).

In this method, the relationship between weight loss and organic carbon content must be calibrated, adjusting the applied temperatures according to the soil type. Typical temperatures range from 350°C to 450°C (Izquierdo, J. & Arévalo, J., 2021), as higher temperatures can lead to overestimation of organic carbon. This overestimation occurs not due to combustion of organic components, but due to dehydroxylation of clays (Apesteguia, M et al., 2018).

Equation 10. Calculation of the Soil Organic Matter Fraction for Sample i Proposed by Schulte and Hopkins (1996) (Barrezueta-Unda, S. et al., 2020)

$$\%MOS = \frac{(PSI - PSC)}{PSI} * 100$$

Where:

[14] The initial application of this method will require calibration of time and temperature parameters against TOC results, or a clear justification supported by scientific evidence, and must correspond to information equivalent to the project area or soil types involved.

$\%MOS$: Percentage of Soil Organic Matter in the sample. Expressed as a percentage (%).
PSI: Initial weight of the sample (after initial moisture drying) – normally carried out at 105°C or air-dried, expressed in g or kg.
PSC: Final weight of the sample after the calcination period – The temperature and duration of calcination will depend on the protocol and associated variables, as well as on the soil type. Expressed in g or kg.

Once the Soil Organic Matter content has been determined, a conversion factor is applied according to the percentage of Carbon contained in the organic matter or fraction (commonly assumed to be 58%) (Barrezueta-Unda, S. et al., 2020).

The use of calcination protocols and the selection of conversion factors must be supported by scientific and/or technical references that substantiate such data. These must also be consistent with the soil type and/or land cover analyzed, maintaining conservative approaches and ensuring data quality in accordance with Section 7.2 of this module.

6.1.3.2 Other Thermo-Analytical Methods

Various analytical or estimation methods may be used to determine the soil organic fraction, from which the final estimation of Soil Organic Carbon (SOC) content can be derived. These methods are based on the exothermic reactions exhibited by organic fractions at lower temperatures than inorganic fractions. Among these alternatives are: TGA – Thermogravimetric Analysis, DTA – Differential Thermal Analysis, DSC – Differential Scanning Calorimetry, Programmed pyrolysis, Evolved gas analysis, TG-IR or MS or GS – Thermogravimetry coupled with infrared spectroscopy, mass spectrometry, or gas chromatography (Apesteguia, M. et al., 2018), among other existing or emerging methods.

The application of these methods must be duly justified and explained in detail, and must comply with the statistical and data quality criteria described in Section 7.2 of this module.

6.1.4 Use of Default Factors

Parameters established by the Intergovernmental Panel on Climate Change (IPCC) [15]. may be used for estimating both stocks and changes in SOC levels. In such cases, all applicability guidelines determined by the IPCC must be considered and applied to the entire project area.

[15] 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

6.2 Baseline

The definition of the historical analysis period for establishing the baseline scenario shall be determined by the methodology applied under the PMGEI and shall correspond to the soil conditions and scenario in the absence of the project. All considerations applicable to the carbon pool as indicated in the corresponding methodologies must be considered, as well as the specifications for the two scenarios described below:

Scenario A: If the initiative begins implementation at t0, the baseline scenario must be formulated using historical SOC data reported for the project area (or ecologically equivalent areas) in accordance with the time horizon specified in the selected methodology. This shall be based on official or secondary information that is technically and/or scientifically supported. If historical information on Soil Organic Carbon (SOC) content is not available for the project area, baseline SOC stocks may be defined using default values that associate organic carbon content with the land use prior to implementation of the initiative (see Illustration 2).

Scenario B: If a project already under implementation reports SOC as one of its carbon pools and estimates associated removals, the baseline value shall correspond to the average of the values reported in its previous monitoring events up to the current reporting period, regardless of the quantification method used (see Illustration 2). This shall consider the existence of SOC within the project boundary and its increase following implementation of the activity. If SOC had not been previously reported and no historical information is available, the project must select an appropriate value (either default or field-measured) consistent with the land use during the crediting period already implemented or at that point in time.

The value determined under the baseline scenario must be subtracted from the quantification obtained under the project scenario for each monitoring period.

The determination of SOC stocks or emissions associated with impacts on this carbon pool must be quantified as described in this module (see Section 6.4 Other Emissions). These SOC quantifications shall be integrated into the overall calculation of project emissions and/or removals, where the corresponding deductions (emissions, baseline, leakage, etc.) will be applied to determine the final total emissions and/or removals for the analyzed period.

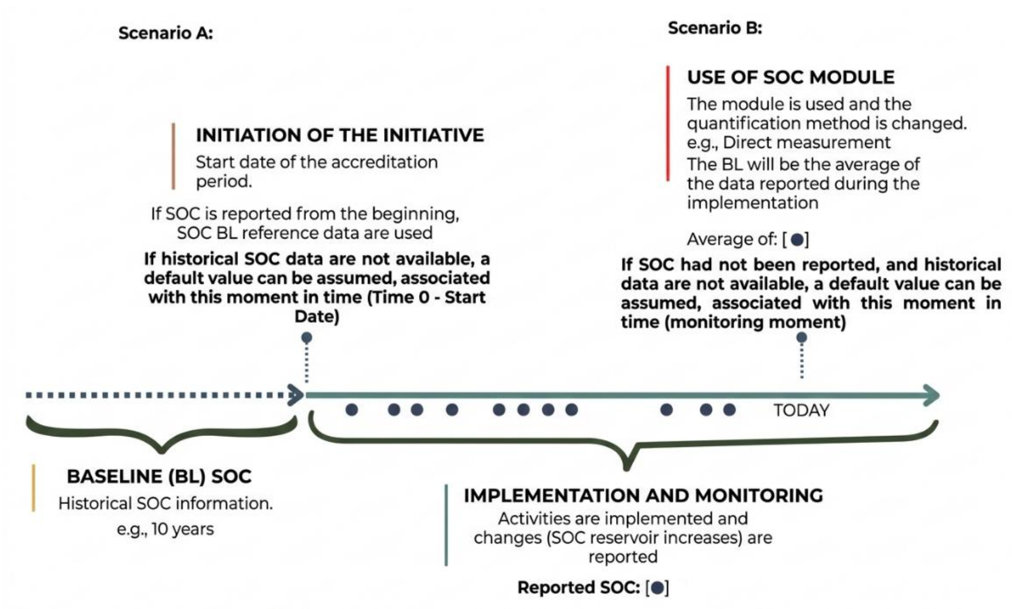

Illustration 2. Baseline Determination Scheme for Projects in the Implementation Stage

6.3 Project Scenario

Under the project scenario, SOC pools must be quantified following the calculation guidelines described above. As with the baseline, SOC quantifications must be integrated into the overall calculation of project emissions and/or removals, where the corresponding deductions will be applied to determine the final total project emissions and/or removals for the analyzed period.

The change in soil organic carbon stocks within the project between two points in time is calculated as follows:

Equation 11. Change in soil organic carbon stocks

$$\Delta C_{COS,ti} = \frac{C_{COS,ti} - C_{COS,tj}}{T}$$

Where:

$\Delta C_{COS,ti}$	Change in total carbon in the project area stored in soil at time i (tCO_2e/year)
$C_{COS,ti}$	Total carbon in the project area stored in soil at time i (tCO_2e)
$C_{COS,tj}$	Total carbon in the project area stored in soil at time j (tCO_2e)
T	Time elapsed between two successive measurements (years)
j	Year of the current project monitoring event (years)
i	Year of the preliminary project monitoring event (years)

6.4 Other Emissions

Although certain project activities may contribute to increases in SOC content, emissions or reductions associated with the implementation of soil management practices must be quantified and accounted for by the PMGEI in accordance with the guidelines set out in the applicable methodology.
Accordingly, this module does not address the calculation of other carbon pools or other activities that generate or reduce emissions and is solely focused on the quantification of SOC within the different PMGEI to which it applies.

7 MONITORING

The project must report changes in SOC stocks in accordance with the selected quantification method and within a defined time. In the case of direct sampling, the data to be reported shall correspond to the results obtained in each sampling exercise conducted. In the case of stock modeling, the trend will depend on the quantity and accuracy of the carbon stock data available for this pool, that is, the number of measurements used to construct and calibrate the model.

During different verification periods and according to the method used, information on changes in this pool and the carbon stocks measured during each period must be reported and adjusted accordingly (depending on the quantification approach).

7.1 Parameters to Monitor

For monitoring SOC content in soils within the project area, each monitoring report must evaluate and/or report at a minimum the following parameters:

- Selected stratification variables
- Land uses and land cover
- Sampling mechanisms used for quantification
- Sample extraction or collection methods
- Specific bulk densities – depending on the fractions present in the samples
- Location of sampling sites – geographic coordinates
- Date of sample collection and measurement
- Carbon content in grams (g) or percentage (%)
- Soil organic carbon content by depth, sampling unit, stratum, and for the total project area
- Management practices implemented in the project soils.

7.2 Data Quality and Assurance

Quality and consistency in information management and data collection must be ensured in order to contribute to the integrity, traceability, and reliability of results. To this end, standardized protocols for soil sampling, handling, and analysis must be implemented, along with regular equipment calibration and technical staff training. Additionally, the project developer must apply quality control procedures such as duplicate analyses, control samples, and the use of certified reference materials. Detailed documentation must be provided in the “Monitoring Report” (Section C – Information on the implemented monitoring system), covering all steps from field collection to laboratory processing and statistical analysis.

In the estimation process, regardless of the method used, uncertainty must be calculated based on the parameters established in the “Guidelines for the Identification of Reversals, Non-Permanence Risk, and Uncertainty,” which outlines the general procedure for its estimation, thresholds, and other considerations, in accordance with the guidelines of the Intergovernmental Panel on Climate Change (IPCC).

Furthermore, the inclusion of results from this carbon pool in total estimates must account for the defined uncertainty propagation parameters.

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Document History

Version	***Date***	***Description***
1.0	29/01/2026	Initial version