ECORA Carbon Credit Certification Program

Document: MOEC001 – Carbon Measurement in Vegetation Module

Public Consultation Stage

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1. Acronyms and Definitions

Term	Definition
Aboveground Non-Woody Biomass (BNL_Ab)	Includes all living biomass of aboveground vegetation that does not have a lignified stem structure, including herbaceous plants, subshrubs, and herbaceous lianas.
Aboveground Woody Biomass (BAb)	Includes all living biomass from aboveground vegetation that has a stem with vascular cambium, such as trees and shrubs. Woody lianas, bamboos and taquaras, tree ferns, and palms with lignified stems will also be considered, provided they have their own biomass estimation method.
Baseline Scenario (BS)	Reference scenario quantified against which the mitigation effects of GHG provided by the project are measured, representing the emissions and/or removals that would occur in the absence of the implementation of the Project Activity, serving as a parameter to calculate the climate benefits generated.
Belowground Non-Woody Biomass (BNL_Ac)	Includes all living biomass belonging to the roots of aboveground non-woody vegetation.
Belowground Woody Biomass (BAc)	Includes all living biomass belonging to the roots of woody vegetation.
Biome	Definition applied to Brazil by IBGE that delimits a set of life (plant and animal) constituted by the grouping of contiguous and regionally identifiable types of vegetation, with similar geoclimatic conditions and a shared history of changes, resulting in its own biological diversity. The following continental biomes of Brazilian territory are considered: Amazon Biome, Atlantic Forest Biome, Caatinga Biome, Cerrado Biome, Pantanal Biome, and Pampa Biome.
Commercial Wood	Refers to wood from forest species classified as commercial in the context of sustainable forest management, characterized by recognized economic value, market demand, and suitability for industrial or structural use. These species are typically considered in forest inventories and production planning, being used for estimations of exploitable volume, definition of cutting cycles, and assessment of the economic viability of management.

Term	Definition
Dead Wood (DW)	Dead woody components located above the ground, including standing dead trees, logs, branches, and fallen wood fragments, with a diameter equal to or greater than the minimum threshold adopted in the aboveground live woody biomass inventory.
Deforestation	Anthropogenic intervention that results in the removal of native vegetation from an area with conversion to another land use.
Degradation	Losses of carbon stock from native vegetation without conversion to another land use.
Disturbance	Losses of carbon stock caused by natural events such as fires, storms, hurricanes, extreme drought events, floods, etc.
Litter (LT)	Organic material recently deposited on the soil, composed of leaves, fine branches, fruits, flowers, and other plant debris at different stages of decomposition. This reservoir represents the transient fraction of ecosystem carbon, located above the soil surface and below the living vegetation.
Project Area Stratum	Subdivision of the area of interest defined to group or separate areas according to the characteristics that influence carbon stock. The strata concentrate areas that are homogeneous in relation to carbon stock or the factors that determine it, such as vegetation type, development stage, land use, or management practices.
Project Designer	Individual or legal entity formally designated by the Project Proponent to develop, monitor, and be technically responsible for a project for emission reductions or GHG removals. The Project Designer may be the Project Proponent themselves or a different entity, provided there is a formal delegation of responsibilities. The Project Designer does not hold legal rights over the project or the credits generated, except when they are also the Project Proponent by express legal ownership.
Project Start Date	Date on which the activities that led to the generation of emission reductions or GHG removals began to be implemented.
Soil Organic Carbon (SOC)	Corresponds to the carbon stock present in soil organic matter, including decomposing plant residues, fine roots, and stable organic compounds associated with mineral fractions, representing the

Term	Definition
	fraction of carbon retained in the soil below the surface.
Uncertainty	Lack of knowledge of the true value of a variable that can be described by a Probability Density Function (PDF), characterizing the range and probability of possible values. Uncertainty depends on the analyst's state of knowledge, which in turn depends on the quality and quantity of applicable data, as well as knowledge of underlying processes and inference methods.
Wood Products (WP)	Products derived from extracted woody biomass, including sawn wood, plywood, panels, paper, and other forest-based products with different lifespans.

2. Introduction

The potential for carbon credit generation of a project is directly related to the carbon stock of the reservoirs included in the project. In this context, the quantification of carbon stocks is an essential step for the consistency of AFOLU carbon credit projects. The MOEC001 – Carbon Measurement in Vegetation Module aims to establish guidelines for the quantification of carbon stocks in the main reservoirs applicable to Agriculture, Forestry, and Other Land Use (AFOLU) projects, including: Aboveground and Belowground Woody Biomass, Aboveground and Belowground Non-Woody Biomass, Soil Organic Carbon, Litter, Dead Wood, and Wood Products.

The application of MOEC001 – Carbon Measurement in Vegetation Module guides Project Designers in identifying data collection methods for each carbon reservoir, prioritizing secondary data sources, and providing applicable equations, in order to allow the determination of the average carbon stock to be used in the calculation of the applied methodology.

This document consists of eighteen sections, namely: (1) *Acronyms and Definitions*, which contains the technical terms, concepts, and acronyms used throughout the document; (2) *Introduction*, which provides background information on MOEC001 – Carbon Measurement in Vegetation Module and its objective; (3) *Module Structure*, which briefly describes the structure of the Module; (4) *Applicability*, which defines the scope of use of the module; (5) *Assessment Frequency*, which defines the timing of carbon stock measurements; (6) *Primary Data Collection*, which provides guidelines for obtaining data in the field; (7) *Use of Secondary Data*, which establishes guidelines for using data from the literature; (8) *Stratification of the Project Area*, which specifies the procedures for stratifying the Project Area; (9) *Aboveground and Belowground Woody Biomass*, which details the procedures for data collection and quantification of the average carbon stock for these reservoirs; (10) *Aboveground and Belowground Non-Woody Biomass*, which presents the procedures for data collection and quantification of the average carbon stock for these reservoirs; (11) *Soil Organic Carbon for Projects Where Quantification Is Optional,* which sets forth the procedures applicable to these cases; (12) *Soil Organic Carbon for Projects Where Quantification Is Mandatory*, which establishes the procedures for these projects; (13) *Litter*, which addresses the quantification of the average carbon stock in this pool; (14) *Deadwood*, which addresses the procedures for quantifying the average carbon stock in this pool; (15) *Wood Products*, which describes the procedures for quantifying the average carbon stock in this pool; (16) *Requirements for the Application of Equations*, which defines the requirements for using equations derived from the literature; (17) *Uncertainties*, which presents the factors that must be considered when estimating the uncertainties associated with carbon reservoirs; and (18) *Evidence*, which specifies the minimum evidence that must be submitted to the VVB. Additionally, Appendix A presents the laboratory procedures for determining soil organic carbon in soil samples.

3. Module Structure

The MOEC001 – Module for Carbon Measurement in Vegetation establishes the guidelines that Project Designers must follow for the initial establishment and periodic measurement of carbon stocks, including the definition of measurement frequency in the Baseline Scenario, when applicable. The document also describes procedures for data collection and sampling and provides guidance on the use of secondary data sources.

Additionally, the module addresses the quantification of biomass in different carbon reservoirs and vegetation types, including the application of equations and conversion factors compatible with the type of vegetation and carbon reservoir. The document presents the recommended factors to be considered in the calculation of uncertainty associated with carbon stocks and the minimum evidence that the Project Designer must include in the Project Design Document (PDD). The result of applying MOEC001 – Carbon Measurement in Vegetation Module is the average carbon stock value per stratum of the Project Area that the Project Designer must apply in the methodology used.

The Flowchart presented in Figure 1, shows the logical sequence of the main guidelines addressed in this module, as well as the carbon reservoirs covered, with the aim of facilitating the understanding of the carbon stock measurement process to be applied in the methodology in question.

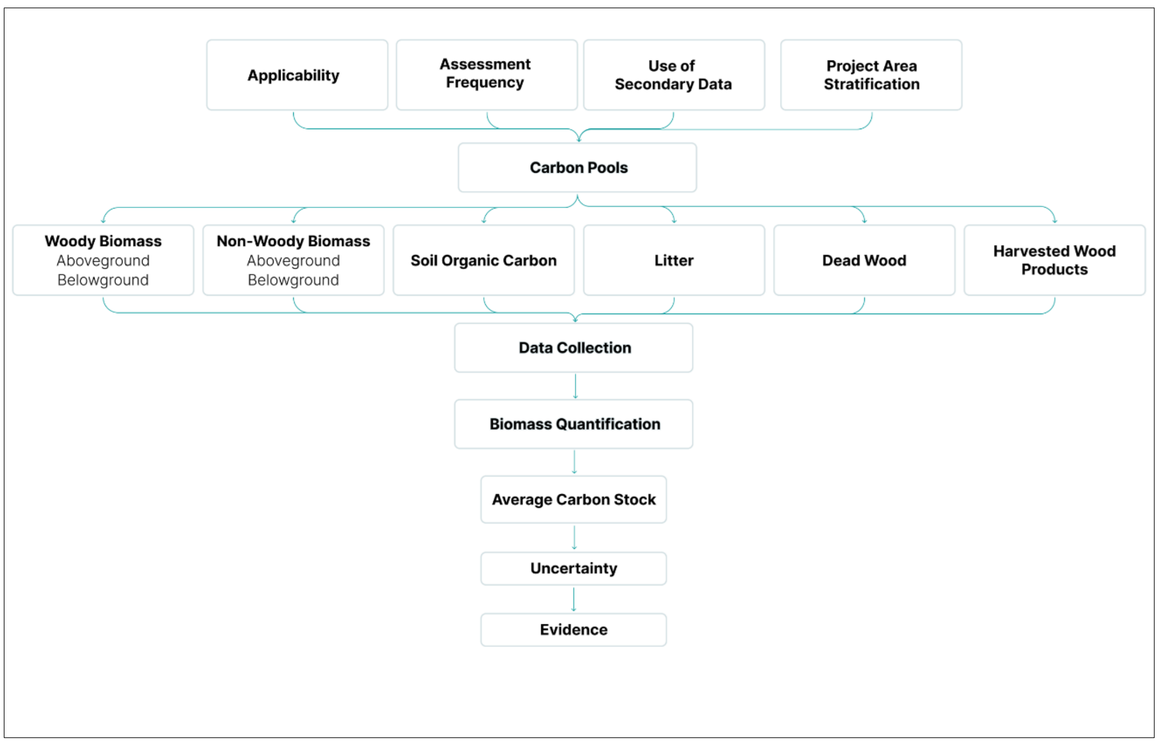

Figure 1. Structural flowchart of the module.

4. Applicability

This module must be applied for the quantification of carbon stocks in AFOLU sector projects. Alternative or complementary measurement and modeling methods may be used by the Project Designer, provided they are accompanied by technical justification and evidence that prove their local applicability and do not result in reduced accuracy when compared to the methods proposed in this module.

Alternative or complementary methods are subject to analysis and approval by the ECORA Carbon Credit Certification Program and by Validation and Verification Bodies (VVB), in order to verify compliance with the applicable methodological requirements.

5. Assessment Frequency

The first measurement of carbon stocks must be carried out within the five-year period preceding the Project Start Date. These measurements must be updated at intervals of up to five years during the project's Crediting Period. If the applied methodology presents specific rules regarding the first measurement and the frequency of updates different from those set out in this document, the Project Designer must follow the specifications of the methodology.

6. Primary Data Collection

The Project Designer must select the field methodology for primary data collection according to the reservoir of interest and the specifications applicable to each reservoir. To define the data collection procedure, the following hierarchy of reference sources should be followed:

a. National inventory field manual. In the absence of this manual or when there is no information for the reservoir or collection technique of interest, the Project Designer must proceed to item b of this hierarchy.

b. Methodologies described in scientific articles indexed on the SciELO, Web of Science, and Scopus platforms.

Regardless of the collection procedure adopted, the Project Designer must meet, in addition to the requirements established in the specific sections of each reservoir, the following criteria:

a. For the global average of the Project Area, the sampling error for each carbon reservoir must be ≤20% with a confidence interval of at least 90%. If the sampling error found is above 20%, the Project Designer must make adjustments to the sampling design or to the data collection and analysis procedures to meet the established statistical requirement.

b. For reservoirs considered optional in the applied methodology, the sampling error value may exceed the 20% limit provided that this condition is justified in the PDD, not exceeding 30%.

The Project Designer must present as evidence in the PDD, the data collection procedure methodology(ies) employed for primary data.

7. Use of Secondary Data

The use of secondary data, such as biomass data, conversion factors, and parameters used for the quantification of biomass in the reservoirs covered in this module is permitted, provided it follows the instructions presented in item 7.1. The use of secondary data in the validation and/or verification phases is permitted when provided for in the applied methodology.

7.1. Reference Sources for Secondary Data

The Project Designer may use biomass data from scientific literature, provided it is in accordance with the stages of the certification process in which the use of secondary data is permitted, as established in each methodology. The Project Designer must follow the hierarchy of reference sources below:

a. Regional data obtained from scientific articles indexed in the *SciELO, Web of Science* and *Scopus* platforms. The data must come from a study with a sampling error equal to or less than 20% and with a confidence interval of at least 90%. When the value of the regional data is less conservative than that available in the national inventory officially consolidated by the country where the project is located (for example, average carbon stock value in the aboveground woody biomass reservoir in the Baseline Scenario of the regional data higher than the national inventory data), the Project Designer must use the national inventory data;

b. Data from the officially consolidated national inventory in the country. For projects in Brazil, the Project Designer must use the most recent version of the National Inventory of Anthropogenic Greenhouse Gas Emissions and Removals; Data from the *Guidelines for National Greenhouse Gas Inventories*, from the IPCC.

All data sources used must be referenced, including author, year, publication or database.

The Project Designer must assess the applicability of the data provided by the national inventory to their Project Area. In reservoirs where the national inventory does not provide the data, the Project Designer must follow the provisions regarding regional data and always prioritize conservatism. When the Project Area is stratified, the Project Designer must present data that are compatible at the phytophysiognomy level (or actual formation, according to the IBGE definition) for each stratum. Additionally, the data must refer to the same biome in which the stratum is located.

The indexing platforms SciELO, *Web of Science*, and Scopus were adopted as references for the selection of scientific articles, as they conduct formal evaluation processes led by scientific committees and/or editorial teams, based on technical and editorial criteria, including but not limited to peer review, quality of journal articles, and contribution to the thematic area.

7.2. Soil Organic Carbon Reservoir

For the Soil Organic Carbon reservoir, the Project Designer may use data from Publications of Research Institutions consolidated in the country and from scientific literature, provided that it complies with the stages of the certification process in which the use of secondary data is permitted, as established in each methodology. The Project Designer must follow the hierarchy of reference sources below:

a. Data from official and recognized sources, including platforms and institutions such as MapBiomas, IBGE, EMBRAPA, and *SoilGrids*, provided that their most updated versions are adopted and are methodologically consistent with the scope of the project;

b. Regional data obtained from scientific articles indexed on the SciELO, *Web of Science* and Scopus platforms. The data must come from a study that presents a sampling error equal to or less than 20%. Secondary data applicable to soil organic carbon must contain information on soil density and soil organic carbon content, compatible with the target depth established for the project. The Project Designer must present the methodologies employed by the selected secondary sources mentioned above, based on peer-reviewed scientific publications.

8. Project Area Stratification

When the Project Area presents heterogeneity in relation to the amount of biomass, the Project Designer must stratify the area into homogeneous strata, each with its own characteristics and spatially delimited. Stratification must be carried out considering, but not limited to, the following criteria:

a. Carbon stocks (when the average of a given area presents a variation equal to or greater than ±20% in relation to the global average of the Project Area, this area must be classified as a new stratum);

b. Type of vegetation or phytophysiognomy, considering the intrinsic characteristics of each phytophysiognomy;

c. Detection of degradation and disturbances.

Each stratum must have its definition and delimitation technically justified in the PDD, containing the purpose of the stratification, data used, and decision criteria. The delimitation of each stratum must be presented in a georeferenced map. The delimitation of the stratification can be defined by means of:

a. Carbon stocks:

    i. Aerial surveys with relevant sensors (e.g., LiDAR and RGB) for biomass estimation and differentiation of strata; or

    ii. Secondary data following Section 7.

b. Types of native vegetation:

    i. Secondary data, with the classification of different types of vegetation (e.g., IBGE and MapBiomas); or

    ii. Interpretation of aerial photographs or high-resolution satellite images for delimitation of homogeneous strata.

c. Detection of degradation and disturbances:

    i. Geospatial data or interpretation of aerial photographs or high-resolution satellite images for delimitation of disturbances such as fire, landslides, flooding, or any disturbance and/or degradation that compromises the carbon stock;

    ii. Official or technically valid documentation that proves planned degradation resulting from a forest management plan, including, when applicable, authorizations, approved plans, operational maps, or other equivalent documents that allow its spatial delimitation.

9. Aboveground and Belowground Woody Biomass

This section establishes the guidelines for quantifying carbon stocks in the Aboveground Woody Biomass and Belowground Woody Biomass reservoirs, as defined in Section 1.

9.1. Data Collection

The Project Designer may use primary data, secondary data, or the integration of primary data with remote sensing techniques. For each type of data adopted, the procedures for data collection, processing, and use must be properly outlined in the PDD.

The data collected in the field must include the appropriate variables for quantifying Aboveground and Belowground Woody Biomass, for each type of woody individual, such as the metrics below, but not limited to:

a. Diameter at 1.3 m above ground (DBH, cm) when measurement is carried out in forest or Diameter at 30 cm above ground (DAS, cm) when measurement is carried out in savanna;
    i. The Project Designer must present the justification for the choice of the variable used (DBH or DAS), based on the one that best represents the woody individuals to be included in the measurement;
    ii. The minimum diameter considered must be aligned with the field methodology adopted, and the equation used to estimate biomass must be compatible with the diameters observed in the inventory. These values must be maintained throughout the entire Crediting Period;
    iii. In the case of trees or shrubs with multiple branches, the Project Designer must define a minimum diameter at which all trunks with equal or greater values must be included;
    iv. This variable is mandatory for all inventories
b. Total height of the individual (Ht, m) or stem height (Hf, m);
c. Wood density (ρ): values at the species, genus, or plant community level will be accepted, when applicable. Wood density data may be referenced from scientific literature if not available in the references cited in Section 7 of this module;
d. The choice of variables must be justified in the PDD, demonstrating their application for quantifying Aboveground and Belowground Woody Biomass.

The choice of sampling method must contribute to statistical representativeness and consider:

a. When there is heterogeneity, the area must be stratified, represented by the possibility of differences in carbon stock among the areas considered. The Project Designer must follow the provisions in Section 8;
b. Sampling may be random or systematic; the procedure must follow recognized technical protocols, in order to contribute to the statistical representativeness of the sampling units.
c. The georeferencing of sampling units must be carried out with GNSS receivers (Global Navigation Satellite System), with horizontal positional accuracy ≤ five meters;
d. The sampling units must be represented by fixed or variable plots, with the format to be defined by the Project Designer and justified in the PDD;
e. The sampling units must have a minimum size adequate for sampling the vegetation of the stratum, justified in the PDD;
f. Changes in field plots during the Crediting Period must be justified in the Verification Reports and evaluated by the VVB;
g. The georeferencing procedure must be properly documented in the PDD by the Project Designer.

Use of remote sensors for quantification of Aboveground Woody Biomass

For remote sensing data, the quantification or extrapolation of Aboveground Woody Biomass can be performed with the aid of airborne laser scanning (ALS - *Airborne Laser Scanning)* across the entire Project Area, or by scanning representative subplots of the Project Area.

To obtain aboveground woody biomass using ALS, the Project Designer must carry out, at a minimum:

a. Field vegetation inventory;
b. Scanning of areas with airborne LiDAR obtained by drones, helicopters, or airplanes:
    i. The LiDAR overflight must occur so as to correspond to the same stage of vegetation development represented by the inventory;
    ii. It is mandatory to overlap the field plots with the LiDAR overflights.
c. Data processing and transformation of the point clouds into structural variables;
d. Development of predictive models that relate LiDAR variables to the biomass data measurements obtained from the field inventory;
e. The predictive model must be used to extrapolate the calculation of aboveground woody biomass (BAc) for the entire Project Area.

Regarding the acquisition of data obtained by aerial survey:

a. The acquisition of ALS data must have an average point density sufficient to generate a digital elevation model (DEM) with a resolution of one meter or higher over the observed area:
    i. The Project Designer must contribute to the vertical accuracy of the DEM by following methods present in nationally and internationally consolidated standards and guidelines (e.g., ASPRS (2014), NSSDA, and USGS *Lidar Base Specification*);
    ii. The Project Designer should consult previous studies in similar ecosystems or conduct a pilot sampling to adopt best practices.
b. The scan angle must be less than or equal to 12 degrees, with the recommendation that smaller angles be used in vegetation where the canopy is closed, that is, where the canopy opening allows little laser penetration into the lower strata.

In these cases, two types of sampling will be possible:

a. Total coverage (most recommended): the overlap along the flight line and between flight lines must be greater than 50%;
b. Subplot sampling: a minimum coverage of 30% of the Project Area is required, and a simple systematic sampling design for the flight lines.

Regarding the field plots related to data obtained by aerial survey:

a. They must be allocated by stratum;
b. Their 4 vertices must be georeferenced. In the case of circular plots, the Project Designer must ensure that the plots are georeferenced so that they are fully captured within the LiDAR point cloud. Georeferencing must be carried out with GNSS receivers, with horizontal positional accuracy ≤ five meters;
c. They must be fixed and distributed so as to represent the vegetation of the area or stratum;
d. They must not be smaller than the pixel size of the aboveground biomass map;
e. The variables collected must follow the guidelines described in item 9.3 “Data collection”.

Regarding the processing of the LiDAR point cloud, the Project Designer must consider:

a. The minimum height threshold considered in the LiDAR point cloud must be defined and technically justified based on:

i. Field data that demonstrate compatibility between the threshold and the structure of the sampled vegetation or

ii. Peer-reviewed scientific references conducted in ecosystems with similar structural characteristics.

For the statistical modeling of data obtained by LiDAR, the following must be considered:

a. The Project Designer must justify the choice of model, provided it is based on approaches recognized in peer-reviewed scientific studies or applied by governmental institutions or national protocols;

b. The model must present, at a minimum:

   i. Coefficient of determination (R^2) ≥ 0.8;

   ii. Root mean square error of prediction (relative RMSE) ≤ 10%;

   iii. If the statistical parameters do not reach the specific minimum values, the Project Designer may adopt new values for R^2 and RMSE, provided they do not exceed the thresholds of 0.7 and 20%, respectively.

c. Parameters used in the equations, the standard error of the estimate (Syx), and the graphical analysis of the residuals.

Regarding the mapping of Aboveground Biomass obtained with the aid of LiDAR:

a. The Project Designer must generate a continuous map of aboveground woody biomass (BAc) covering the corresponding stratum or the entire Project Area, in the absence of stratification, by applying the selected predictive model.

b. The mapping must be carried out on a regular grid, with a defined pixel size, consistent with:

   i. The dimensions and arrangement of the field plots: the pixel size must at least correspond to the size of the plots used in the field.

9.2. Biomass Quantification

Aboveground Woody Biomass

When the quantification of aboveground woody biomass is carried out using primary or secondary data, the Project Designer must:

a. Determine the average aboveground woody biomass, according to Equation 1:

$$B_{Ac,,e} = \frac{1}{n}\sum_{pa=1}^{n} B_{Ac,pa,e} \qquad (1)$$

Where:

$B_{Ac,,e}$= Average aboveground woody biomass in stratum “e” (t ha^{-1});

$B_{Ac,pa}$ = Aboveground woody biomass per sampled plot in stratum “e” (t ha^{-1});

pa = Sampled plot, ranging from 1 to “n”;

n = Total number of plots considered in the sampling;

e = stratum 1, 2, 3 .... n

b. Convert the total woody biomass into total equivalent carbon stock, according to Equation 2:

$$C_{BAc,e} = (B_{Ac,,e} * FC) * \frac{44}{12} \quad (2)$$

Where:

$C_{BAc,,e}$= Average carbon stock stored in aboveground woody biomass in stratum “e” (tCO_2e ha^{-1});

$B_{Ac,,e}$= Average aboveground woody biomass in stratum “e” (t ha^{-1});

FC = Conversion factor from dry matter to carbon [tC (t d.m.)$^{-1}$]. For projects in Brazil, use data from the National Communication. For projects outside Brazil, use IPCC data;

$\frac{44}{12}$ = Molecular conversion factor from carbon to carbon dioxide equivalent [tCO_2 $(tC)^{-1}$];

e = stratum 1, 2, 3 .... n.

If the Project Designer has their own measured data for the dry matter to carbon conversion factor, these data may be used. The methodology used for data collection, processing, and analysis must be properly documented, presented to the Validation and Verification Body (VVB), and submitted for its validation.

When the quantification of aboveground woody biomass is performed using remote sensing data, the Project Designer must:

a. Calculate the average aboveground woody biomass, according to Equation 3:

$$B_{Ac,,e} = \frac{\sum_i (B_{Ac,pixel,i,e} * A_{pixel,i,e})}{\sum_i A_{pixel,i,e}} \quad (3)$$

Where:

$B_{Ac,e}$ = Average aboveground woody biomass in stratum “e” (t d.m. ha^{-1});

$B_{Ac,pixel,i,e}$= Aboveground woody biomass of the aerial part in pixel “i” in stratum “e” (t d.m.ha^{-1});

$A_{pixel,e}$ = Pixel area in stratum “e” (ha);

e = stratum 1, 2, 3 .... n;

i = considered pixel;

b. Convert the value of average aboveground woody biomass into average equivalent carbon stock, according to Equation 4:

$$C_{BAc,e} = (B_{Ac,e} * FC) * \frac{44}{12} \quad (4)$$

Where:

$C_{BAc,e}$= Average carbon stock stored in aboveground woody biomass in stratum “e” (tCO_2e ha^{-1});

$B_{Ac,e}$ = Average aboveground woody biomass in stratum “e” (t d.m. ha^{-1});

FC = Conversion factor from dry matter to carbon [tC (t d.m.)$^{-1}$] For projects in Brazil, use data from the National Communication. For projects outside Brazil, use IPCC data;

$\frac{44}{12}$ = Molecular conversion factor from carbon to carbon dioxide equivalent [tCO_2 $(tC)^{-1}$];

e = stratum 1, 2, 3 .... n.

If the Project Area contains bamboos, lianas, tree ferns, and palms, the Project Designer may include them in the project provided that specific biomass estimation equations for these species are used, according to the guidelines in Section 16.

Belowground Woody Biomass

The Project Designer must use relationships between aboveground and belowground biomass from officially recognized and validated sources in the country (follow the guidelines in Section 7 of this document). The total equivalent carbon stock must be calculated according to Equation 5:

$$C_{BAb,e} = R * C_{BAc,e} \tag{5}$$

Where:

$C_{BAb,e}$ = Average carbon stock stored in belowground woody biomass in stratum "e" (tCO_2e ha^{-1});

$C_{BAc,e}$= Average carbon stock stored in aboveground woody biomass in stratum "e" (tCO_2e ha^{-1})

R = Root to shoot ratio;

e = stratum 1, 2, 3 .... n.

10. Aboveground and Belowground Non-Woody Biomass

This reservoir includes the components of Aboveground Non-Woody Biomass and Belowground Non-Woody Biomass, as defined in Section 1.

10.1. Data Collection

The Developer of the Project may choose primary data, secondary data, or the integration of primary data with remote sensing techniques. For each type of data used, the Project Designer must follow the provisions and requirements defined in this module and in the applicable methodology.

For each type of data adopted, the procedures for data collection, processing, and use must be properly documented in the PDD. The collection of non-woody biomass can be carried out through direct or indirect sampling, with direct sampling being recommended. Indirect sampling consists of estimating biomass from the measurement of correlated variables, applying equations or conversion factors previously established in the adopted field methodology. If the indirect method is adopted, the Project Designer must provide as evidence the collection methodology and the conversion factors used. In both cases, the Project Designer should follow technical protocols recognized by the government of the country where the project is located, as well as by national or international research institutions and peer-reviewed scientific publications.

In cases where remote sensing data are used, the quantification and/or extrapolation of aboveground non-woody biomass can be carried out with the aid of airborne *laser* scanning (ALS). The guidelines for conducting the flights and for the quantification and extrapolation of the data follow those present in Item 9.1.

The Project Designer may use the same LiDAR flight to quantify woody and non-woody biomass, provided that consistent methodologies aligned with the requirements of this module are adopted for both types of biomass.

10.2. Biomass Quantification

Aboveground Non-Woody Biomass

When the quantification of aboveground non-woody biomass is carried out using primary or secondary data, the Project Designer must:

a. Calculate the total aboveground non-woody biomass, according to Equation 6:

$$B_{NL,Ac,e} = \frac{1}{n}\sum_{pa=1}^{n} B_{NL,Ac,pa,e} \qquad (6)$$

Where:

$B_{NL,Ac,e}$ = Average aboveground non-woody biomass in stratum “e” (t d.m. ha^{-1});

$B_{NL,Ac,pa,e}$ = Aboveground non-woody biomass per sampled plot in stratum “e” (t d.m. ha^{-1});

pa = Sampled plot, ranging from 1 to “n”;

n = Total number of plots considered in the sampling;

e = stratum 1, 2, 3 .... n.

b. Convert the average aboveground non-woody biomass into average equivalent carbon stock, according to Equation 7:

$$C_{BNL,Ac,e} = \left(B_{NL,Ac,e} * FC\right) * \frac{44}{12} \tag{7}$$

Where:

$C_{BNL,Ac,e}$ = Average carbon stock stored in aboveground non-woody biomass in stratum “e” (tCO_2e ha^{-1});

$B_{NL,Ac,e}$ = Total aboveground non-woody biomass in stratum “e” (t d.m. ha^{-1});

FC = Conversion factor from dry matter to carbon [tC $(t\ d.m.)^{-1}$] For projects in Brazil, use data from the National Communication. For projects outside Brazil, use IPCC data;

$\frac{44}{12}$ = Molecular conversion factor from carbon to carbon dioxide equivalent [tCO_2 $(tC)^{-1}$];

e = stratum 1, 2, 3 .... n.

When the quantification of aboveground non-woody biomass is performed using sensing data, the Project Designer must:

a. Calculate the average biomass, as per Equation 8:

$$B_{NL,Ac,e} = \frac{\sum_{i=1} B_{NL,Ac,pixel,i,e} * A_{pixel,i,e}}{\sum_{i=1} A_{pixel,i,e}} \tag{8}$$

Where:

$B_{NL,Ac,e}$ = Average aboveground non-woody biomass in stratum “e” (t d.m. ha^{-1});

$B_{NL,Ac,pixel,i,e}$= Aboveground non-woody biomass of the aerial part in pixel “i” in stratum “e” (t ha^{-1});

$A_{pixel,i,e}$ = Area of pixel “i” in stratum “e” (ha);

i = pixel considered.

b. Convert the value of average aboveground non-woody biomass into average equivalent carbon stock, as per Equation 9:

$$C_{BNL,Ac,e} = (B_{NL,Ac,e} * FC) * \frac{44}{12} \tag{9}$$

Where:

$C_{BNL,Ac,e}$= Average carbon stock stored in aboveground non-woody biomass in stratum “e” (tCO_2e ha^{-1});

$B_{NL,Ac,e}$ = Average aboveground non-woody biomass in stratum “e” (t d.m. ha^{-1});

FC = Conversion factor from dry matter to carbon [tC $(t\ d.m.)^{-1}$] For projects in Brazil, use data from the National Communication. For projects outside Brazil, use IPCC data;

$\frac{44}{12}$ = Molecular conversion factor from carbon to carbon dioxide equivalent [tCO_2 $(tC)^{-1}$];

e = stratum 1, 2, 3 .... n.

Belowground Non-Woody Biomass

The Project Designer must use relationships between aboveground and belowground non-woody biomass from sources recognized and validated in the country (as per guidelines in Section 7).

To convert the value of belowground non-woody biomass into total equivalent carbon stock**,** Equation 10 must be used:

$$C_{BNL,Ab,e} = C_{BNL,Ac,e} * R \quad (10)$$

Where:

$C_{BNL,Ab,e}$= Average carbon stock stored in belowground non-woody biomass in stratum “e” ($tCO_2e\ ha^{-1}$);

$C_{BNL,Ac,e}$= Average carbon stock stored in aboveground non-woody biomass in stratum “e” ($tCO_2e\ ha^{-1}$);

R = Root to shoot ratio.

11. Soil Organic Carbon for Projects Where Quantification Is Optional

This pool covers the Soil Organic Carbon component, as defined in Section 1, and presents the requirements applicable to projects in which measurement in this pool is optional. The Project Scope section of the project activity methodology should be consulted to verify whether this pool is optional or mandatory.

11.1. Data Collection

The Project Designer may use primary or secondary data (as per guidelines in Sections 6 and 7). For each type of data used, the Project Designer must follow the provisions and requirements set out in this module and in the applicable methodology.

The Project Designer must adopt soil organic carbon sampling methods established in the scientific literature. The sampling, preparation, and analysis procedures must be aligned with internationally recognized protocols and suitable for the edaphoclimatic conditions and the project's objective.

For each type of data adopted, the procedures for data collection, processing, and use must be properly documented in the PDD.

For the collection of primary data, the delimitation of strata must be carried out when the Project Area presents heterogeneity, and the following data should be considered, but not limited to:

a. Relief;
b. Vegetation typology;
c. Land use;
d. Carbon potential map of the Project Area, recommended;

The sampling plan must specify that each sampled point must be georeferenced using geographic coordinates, with horizontal positional accuracy ≤ five meters. This tolerance does not imply the need for exact centimeter repositioning of the sampling point, but indicates that subsequent samplings should occur at the same sampling point, allowing for an uncertainty radius of up to approximately 5 meters, in order to avoid sampling at different locations for each verification, except with technical justification. Additionally, representativeness should be ensured through a sampling design that provides adequate coverage of small strata (prioritizing, when applicable, the number of plots per stratum instead of a fixed minimum distance) and proper documentation of georeferencing and repositioning procedures for the plots.

Sampling depth for soil organic carbon:

a. It should prioritize the surface horizons, where there is a higher concentration of roots and organic matter input;
b. The depth varies according to the soil type and ecosystem. The Project Designer must carry out sampling, at a minimum, in the 0–10 cm, 10–20 cm, and 20–30 cm layers. Additionally, the Project Designer may carry out measurements in deeper layers. For projects in Brazil, consider SIBCS, and for projects outside Brazil, consider *Soil Taxonomy* and FAO;
c. In inventories, the chosen depth must be standardized and kept constant throughout the entire Crediting Period of the project.

Soil sample collection for soil organic carbon (SOC) analysis:

a. Location of sampling points:

   i. The samples must be collected at a maximum distance of five meters from the point where the bulk density sampling was carried out, so that both samplings represent the same microenvironment and the same edaphic conditions;

   ii. The samples must be collected at the same depths used for bulk density, with mandatory sampling in the 0–10 cm, 10–20 cm, and 20–30 cm layers, and optional sampling in deeper layers.

b. Type and quantity of samples:

   i. For each depth, deformed samples must be obtained, composed of subsamples collected in five repetitions within the same plot.

c. Preparation of the composite sample:

   i. The subsamples must be homogenized in a container, resulting in a composite sample representative of the depth and the sampled plot.

Soil sample collection for bulk density analysis (BD):

a. The samples must be collected using stainless steel volumetric rings;

b. The sampling points must include all depths defined in the soil organic carbon sampling plan.

Coarse rock fragments (> two mm) must be sieved and quantified separately.

11.2. Quantification of Soil Organic Carbon (SOC)

Quantification using secondary data (applicable only in the *ex ante* phase)

The stocks of soil organic carbon after land use conversion must be estimated considering the long-term average value corresponding to the soil stabilization level. This same approach can be used in preliminary *ex ante* estimates of the potential for UCE generation.

Guidelines and methodological bases:

a. The estimate of average carbon stocks after land use conversion must follow IPCC guidelines;

b. The calculation is based on the soil organic carbon stock existing at the initial time (t = 0);

c. This value must be adjusted by change factors that reflect the soil condition under the new land use.

Land use change factors:

a. They correspond to the ratio between the carbon stock in the converted land use and the reference stock;

b. They reflect the expected variation in organic carbon content as a result of land use conversion.

Temporal dynamics of changes in carbon stock:

a. The changes in soil carbon stock resulting from land use change are assumed to be gradual, occurring over 20 years;

b. After this period, the system is considered to reach a new equilibrium, representing the long-term average stock.

The estimate of the average soil organic carbon stock after land use conversion is carried out according to Equation 11:

$$C_{COS,inicial,e} = C_{COS,REF,e} * FLU_e * FMG_e * FI_e \quad (11)$$

Where:

$C_{COS,inicial,e}$= Carbon stock stored as soil organic carbon after land use conversion in stratum "e" (t C ha^{-1});

$C_{COS,REF,e}$ = Reference stock of soil organic carbon for conditions prior to the implementation of the Project Activity, stratified by climate region and soil type, applicable to stratum "e" of the Project Area (t C ha^{-1});

FLU_e (Land use factor) = Factor that represents the change in stock due to the new land use in stratum "e", according to IPCC parameters (dimensionless);

FMG_e (Management factor) = Factor that adjusts the stock according to the level of land management under the new use conditions in stratum "e", according to IPCC parameters (dimensionless);

FI_e (Carbon input factor) = Factor that adjusts the stock according to the level of carbon addition to the soil under the new use conditions in stratum "e", according to IPCC parameters (dimensionless);

e = stratum 1, 2, 3 .... n.

The Project Designer must assess the total area affected by soil disturbance resulting from project implementation activities for each stratum. If this area, disregarding the disturbance already existing in the Baseline Scenario (when applicable), exceeds 10% of the total area of the stratum, the associated carbon loss must be accounted for according to Equation 12:

$$C_{COS,prd,e} = C_{COS,inicial,e} * 0{,}1 \quad (12)$$

Where:

$C_{COS,prd,e}$= Carbon stock stored as soil organic carbon lost due to soil disturbance attributable to the Project Activity in stratum "e" (t C ha^{-1});

$C_{COS,inicial,e}$= Carbon stock stored as soil organic carbon at the beginning of the Project Activity in stratum "e" (t C ha^{-1});

$0{,}1$ = Corresponds to the 10% proportion of soil organic carbon loss, as previously established in the text, representing the estimated proportion of soil organic carbon lost in the first five years after the site preparation year;

e = stratum 1, 2, 3 .... n.

The variation in soil organic carbon stock in the Project Scenario, until the steady state of soil organic carbon content is reached, is estimated using Equations 13, 14, and 15:

$$dC_{COS,e,t} = 0\ para t < t_{pert,e} \quad (13)$$

$$dC_{COS,e,t} = \frac{C_{COS,inicial,e}}{1\ ano} para t = t_{pert,e} \quad (14)$$

$$dC_{COS,e,t} = \frac{C_{COS,REF,e} - (C_{COS,inicial,e} - C_{COS,prd,e})}{20\ anos} para t < t < t_{pert,e} + 20 \quad (15)$$

Where:

$dC_{COS,e,t}$= Variation in soil organic carbon stocks of the Project Area in stratum “e” in year “t” (t C ha^{-1} $year^{-1}$);

$C_{COS,inicial,e}$= Carbon stock stored as soil organic carbon at the beginning of the Project Activity in stratum “e” (t C ha^{-1});

$C_{COS,prd,e}$= Carbon stock stored as soil organic carbon lost due to soil disturbance attributable to the Activity with Project Activity in stratum “e” (t C ha^{-1});

$t_{pert,e}$= Year in which the first soil disturbance occurs in the Project Area in stratum “e”;

20 = Corresponds to the land use change, assumed to be a gradual change over a period of 20 years;

e = stratum 1, 2, 3 .... n;

t = Time in years elapsed since the Project Start Date.

Due to the uncertainties and intrinsic limitations in the accuracy of estimates based on factors adopted in this module, the variation in soil organic carbon stock must not exceed 0.8 t C ha^{-1} $year^{-1}$, according to Equation 16:

$$Se\ dC_{COS,e,t} > 0{,}8\ t\ C\ ha^{-1} ano^{-1}\ então\ dC_{COS,e,t} = 0{,}8\ t\ C\ ha^{-1} ano^{-1} \quad (16)$$

Where:

$dC_{COS,e,t}$= Rate of variation in soil organic carbon stocks of the Project Area in stratum “e” in year “t” (t C ha^{-1} $year^{-1}$);

e = stratum 1, 2, 3 .... n;

t = Time in years elapsed since the Project Start Date.

The variation in soil organic carbon stock for all strata of the Project Areas, in year t, is calculated according to Equation 17:

$$\Delta C_{COS,e,t} = \sum_e A_e * dC_{COS,e,t} * 1\ ano * \frac{44}{12} \quad (17)$$

Where:

$\Delta C_{COS,e,t}$ = Variation in stocks of carbon stored as soil organic carbon in Project Area that meet the applicability conditions of this module, in stratum “e” in year “t” (t CO_2e ha^{-1} $year^{-1}$);

$dC_{COS,e,t}$= Rate of variation in soil organic carbon stocks of the Project Area in stratum “e” in year “t” (t C ha^{-1} $year^{-1}$);

A_e = Area of stratum “e” in the Project Area (ha);

$\frac{44}{12}$ = Molecular conversion factor from carbon to carbon dioxide equivalent [tCO_2 $(tC)^{-1}$];

e = stratum 1, 2, 3 .... n;

t = Time in years elapsed since the Project Start Date.

Quantification Procedures Based on Primary Data

Soil sampling must be carried out separately for each depth defined in the sampling design. For the quantification of total soil organic carbon, the contents determined in each layer must be aggregated by summation, considering the respective depths, in order to represent the total SOC stock at the selected sampling point according to Equation 18:

$$C_{COS,total,a} = \sum \mathrm{C}_{COS,p} * \mathrm{DS}_p * E_p * (1 - FG_p) * 100 \quad (18)$$

Where:

$C_{COS,total,a}$ = Total soil organic carbon content in the sample, at the considered depth (t C ha^{-1});

$\mathrm{C}_{COS,p}$ = Soil organic carbon content in the sample, at the considered depth (gC g^{-1});

DS_p = Bulk soil density at the considered depth (g cm^{-3});

E_p = Thickness of the soil layer at the considered depth (cm);

FG_p = Coarse soil fraction > two mm (%);

100 = Used for conversion of the area unit to hectare (dimensionless);

p = Considered depth of soil sampling (m);

a = soil sample.

The estimate of the average soil organic carbon stock, converted into carbon dioxide equivalents, should be calculated according to Equation 19:

$$C_{COS,e} = \overline{C_{COS,total,a}} * \frac{44}{12} \quad (19)$$

Where:

$C_{COS,e}$= Carbon stock stored as soil organic carbon in stratum “e” (tCO_2e ha^{-1});

$\overline{C_{COS,total,a}}$= Average total carbon stock stored as soil organic carbon in stratum “e” (t C ha^{-1});

$\frac{44}{12}$ = Molecular conversion factor from carbon to carbon dioxide equivalent [tCO_2 $(tC)^{-1}$];

e = stratum 1, 2, 3 .... n;

a = soil sample.

12. Soil Organic Carbon for Projects in which Quantification is Mandatory

This pool covers the Soil Organic Carbon component, as defined in Section 1, and presents the requirements applicable to projects in which measurement in this pool is mandatory. The Project Scope section of the project activity methodology should be consulted to verify whether this reservoir is optional or mandatory.

12.1. Data Collection

The Project Designer must use primary data, in accordance with the guidelines established in Section 11.1. For each type of data used, the Project Designer must follow the provisions and requirements defined in this module and in the applicable methodology.

For each type of data adopted, the procedures for data collection, processing, and use must be properly documented in the PDD.

For the collection of primary data, the same procedures described in Section 11.1 must be followed, in addition to:

a. Collection of samples to a minimum depth of 30 cm in the layers of 0–10 cm, 10–20 cm, and 20–30 cm. Additionally, the Project Designer may carry out measurements in deeper layers, provided that the layers are subdivided (e.g., if the Project Designer chooses to carry out measurements up to a depth of 100 cm, it is recommended to subdivide the layers into intervals such as 30–45 cm, 45–60 cm, 60–80 cm, and 80–100 cm);

b. Direct measurement and monitoring through laboratory analyses (standard approach), as described in Appendix A: Laboratory methods for the determination of soil organic carbon in soil samples;

c. Direct measurement combined with modeling using recognized and peer-reviewed models (for example, *RothC, DayCent, Century*), provided they are properly calibrated and validated;

d. The selection of the model must be appropriate to local conditions (soil type, climate, management practices), data availability, the resources of the Project Designer, and the project scope. Calibration and validation must be conducted on independent data sets, ensuring spatial and temporal consistency;

e. The selected model must enable the quantification of stocks of ($C_{COS,e}$) and/or variations in stocks ($\Delta C_{COS,e,t}$);

f. The collection of disturbed samples for determination of soil particle size analysis is mandatory.

The Project Designer may use the equivalent soil mass (ESM) method combined with linear interpolation to estimate soil organic carbon stocks up to the chosen maximum depth:

a. The procedure is applicable for quantification purposes in Baselines, monitoring, and verification, provided that the methodological criteria established in this document are met.

Sampling requirements:

a. Samples must be collected, at a minimum, in the following vertical stratification: 0–10 cm, 10–20 cm, and 20–30 cm;

b. Each interval must have samples of soil organic carbon and soil density, collected at the same depth and according to a standardized sampling protocol;

c. The layer from 30 cm onwards is optional and aims to allow the estimation of soil organic carbon at greater depths, with unvalidated extrapolations being prohibited; this layer must be subdivided into smaller intervals up to the chosen depth. For example, if the Project Designer chooses to measure up to 60 cm, the subdivision can be made into 30–45 cm and 45–60 cm or into even smaller intervals.

The Project Designer may alternatively adopt methods other than the equivalent soil mass (ESM) with linear interpolation, provided that equal or superior performance in estimating soil organic carbon stocks up to the chosen depth is demonstrated in a technical and transparent manner, including evidence of validation, methodological consistency, and suitability to project conditions.

Equivalent Soil Mass (ESM)

a. The ESM must be used to correct variations of DS_e between scenarios (Baseline vs. Project) or between times (t0 vs. t1);

b. The equivalent depth must be adjusted based on the accumulated soil mass, so that comparisons of $C_{COS,e}$ are made over equivalent soil volumes;

c. The calculation of ESM must follow the guidelines established in Section 12.2, and must be applied consistently in all monitoring campaigns (Fowler et al., 2023).

Linear Interpolation of ESM for Depths from 30 cm Onwards

a. The Project Designer may apply linear interpolation to estimate soil organic carbon in each sample, at discrete points or in intermediate layers along the soil profile at the selected depths from 30 cm onwards;

b. The method must respect the stratified distribution of samples, using continuous values of soil organic carbon content and bulk density for each sampled depth interval;

c. Interpolation is only permitted up to the depth for which physical data collection exists.

12.2. Quantification of Soil Organic Carbon (SOC)

Quantification Procedures Based on Primary Data for the 0 to 30 cm Layer

When the quantification of soil organic carbon is carried out based on primary data, the quantification procedures established in Section 11.2 must be followed. Through this approach, the result obtained will correspond to the $C_{COS,e}$ factor for the 0–30 cm layer, and must be calculated from laboratory data on soil organic carbon content and bulk density, contributing to methodological consistency between sampling campaigns and representativeness of soil conditions at the sampling point.

Quantification Procedures for Equivalent Soil Mass (ESM) for Layers from 30 cm Onwards

The $C_{COS,e}$ for the layers selected from 30 cm onwards must be derived from the same measurement procedures described in Section 11.2. This value will be used as input data for the calculation of Equivalent Soil Mass (ESM), and must representatively reflect the soil conditions at the respective depth.

For the quantification of equivalent soil mass, the Project Designer calculate according to Equation 20:

$$M_{M,e} = M_{T,e} * (1 - k * C_{COS,e}) \quad (20)$$

Where:

$M_{M,e}$ = Mineral soil mass per unit area in stratum “e” (kg m^{-2});

$M_{T,e}$ = Total soil mass per unit area in stratum “e” (kg m^{-2});

$C_{COS,e}$ = Carbon stock stored in soil organic carbon in stratum “e” (gC g^{-1});

k = Consider 1.9 van Bemmlen Factor, according to Fowler et al. al. (2023) (dimensionless);

e = stratum 1, 2, 3 .... n.

The mineral soil mass must be equal to the initial mass (equation 21):

$$M_{M,n,e} = M_{M,i,e} \quad (21)$$

Where:

$M_{M,n,e}$ = Mineral soil mass at the new time or scenario in stratum “e” (kg m^{-2});

$M_{M,i,e}$= Initial mineral soil mass in stratum “e” (reference mass) (kg m^{-2});

e = stratum 1, 2, 3 .... n.

To determine the mineral mass equivalence for correction by equivalent soil mass, use Equation 22:

$$P_{a,e} * DS_{n,e} * (1 - k * COS_{n,e}) = P_{i,e} * DS_{i,e} * (1 - k * C_{COS,i,e}) \quad (22)$$

Where:

$P_{a,e}$ = Adjusted depth (new depth to maintain mineral soil mass) in stratum “e” (cm);

$DS_{n,e}$ = Soil density at the new time in stratum “e” (g cm^{-3});

$COS_{n,e}$ = Soil organic carbon at the new time in stratum “e” (gC g^{-1});

$P_{i,e}$ = Depth at the initial time in stratum “e” (reference) (cm);

$DS_{i,e}$ = Soil density at the initial time in stratum “e” (reference) (g cm^{-3});

$C_{COS,i,e}$ = Soil organic carbon at the initial time in stratum “e” (reference) (gC g^{-1});

k = Consider 1.9 van Bemmlen Factor (dimensionless);

e = stratum 1, 2, 3 .... n.

To determine the required adjusted depth, the applied mineral mass between the two moments must be equalized according to Equation 23:

$$P_{a,e} = P_{i,e} * \frac{DS_{i,e}}{DS_{n,e}} * \frac{(1 - k * C_{COS,i,e})}{(1 - k * COS_{n,e})} \quad (23)$$

Where:

$P_{a,e}$ = Adjusted depth (new depth to maintain mineral soil mass) in stratum “e” (cm);

$P_{i,e}$ = Depth at the initial time in stratum “e” (reference) (cm);

$DS_{i,e}$ = Soil density at the initial time in stratum “e” (reference) (g cm^{-3});

$DS_{n,e}$ = Soil density at the new time in stratum “e” (g cm^{-3});

$C_{COS,i,e}$= Soil organic carbon at the initial time in stratum “e” (reference) (gC g^{-1});

$C_{COS,n,e}$ = Soil organic carbon at the new time in stratum “e” (gC g^{-1});

k = Consider 1.9 van Bemmlen Factor (dimensionless);

e = stratum 1, 2, 3 .... n.

After calculating the adjusted depth, the adjusted carbon stock should be estimated according to Equation 24:

$$C_{COS,crg,e} = P_{a,e} * DS_e * C_{COS,e} * 100 * \frac{44}{12} \quad (24)$$

Where:

$C_{COS,crg,e}$ = Corrected soil organic carbon in stratum “e” (tCO_2e ha^{-1});

$P_{a,e}$= Adjusted depth in stratum “e” (cm or m);

DS_e = Soil density in stratum “e” (g cm^{-3});

$C_{COS,e}$ = Soil organic carbon in stratum “e” (gC g^{-1});

100= Used for conversion of mass per area unit (dimensionless);

$\frac{44}{12}$ = Molecular conversion factor from carbon to carbon dioxide equivalent [tCO_2 $(tC)^{-1}$];

e = stratum 1, 2, 3 .... n.

Therefore, the result represents the $C_{COS,e}$ for the range from 30 cm (e.g., 30–60 cm). Equation 24 must be applied to each sampled layer individually. For example, if the considered layer is 30–60 cm, and if there is more than one measurement of $C_{COS,e}$ within this range, such as in sublayers of 30–45 cm and 45–60 cm, the Project Designer must sum the values of $C_{COS,crg,e}$ for each sublayer.

Thus, the $C_{COS,e}$ for the 30–60 cm range will be equal to the sum of the $C_{COS,crg,e}$ from Equation 24 when there are multiple measurements within the range.

Quantification of Soil Organic Carbon by Stratum

The quantification of soil organic carbon stock will be carried out by summing the carbon stocks of the 0–30 cm layers and from 30 cm (e.g., 30–60 cm), according to Equation 25:

$$C_{COS,e} = C_{COS,e,0-30} + C_{COS,e>30} \quad (25)$$

Where:

$C_{COS,e}$= Carbon stock stored in soil organic carbon in stratum “e” ($tCO_2e\ ha^{-1}$);

$C_{COS,e,0-30}$= Carbon stock stored in soil organic carbon in the 0–30 cm layer, in stratum “e” ($tCO_2e\ ha^{-1}$);

$C_{COS,e>30}$= Carbon stock stored in soil organic carbon in the layer from 30 cm, in stratum “e” ($tCO_2e\ ha^{-1}$);

e = stratum 1, 2, 3 .... n.

13. Litter

This section establishes the guidelines for quantifying carbon stocks in the Litter reservoir, as defined in Section 1.

13.1. Data Collection

The Project Designer must use primary data. For each type of data adopted, the procedures for data collection, processing, and use must be properly described in the PDD.

Sampling Design and Data Collection:

a. The sampling design must be representative and standardized for all strata, aiming for methodological consistency and comparability between verifications;

b. It is necessary to collect all loose organic material (leaves, fine and coarse fragments) up to the point of contact with the mineral horizon or up to the operational limit specified in the protocol.

The Project Designer must justify and indicate the database used for the definition of strata. Within each stratum, the plots must be distributed to obtain adequate spatial coverage, allocated in the field in one of the following ways:

a. Systematic with random start;

b. Grid sampling (regular mesh);

c. Stratified random sampling;

d. Stratified systematic sampling.

13.2. Biomass Quantification

To determine the equivalent carbon stock in the litter, Equation 26 must be applied:

$$C_{SE,e} = \frac{\sum(B_{SE,pa,e} * 10)}{n} * FC_{MS,SE} * \frac{44}{12} \quad (26)$$

Where:

$C_{SE,e}$= Average equivalent carbon stock stored in litter ($tCO_2e\ ha^{-1}$);

$B_{SE,pa,e}$ = Litter biomass in the sampled plot (1x1 meter frame) in stratum "e" (kg d.m.);

10 = Conversion factor from kg d.m. m^{-2} to t d.m. ha^{-1};

$FC_{MS,SE}$= Carbon fraction of dry matter in litter [tC $(t\ d.m.)^{-1}$] For projects in Brazil, use data from the National Communication. For projects outside Brazil, use IPCC data;

pa = Sampled plot, ranging from 1 to "n";

e = stratum 1, 2, 3 .... n

n = number of sampled plots (1x1 meter frame) in stratum "e";

$\frac{44}{12}$ = Molecular conversion factor from carbon to carbon dioxide equivalent [$tCO_2\ (tC)^{-1}$].

14. Dead Wood

This section establishes the guidelines for quantifying carbon stocks in the Dead Wood pool, as defined in Section 1.

14.1. Data Collection

The Project Designer may use primary or secondary data. For each type of data adopted, the procedures for data collection, processing, and use must be properly described in the PDD.

Standing Dead Wood

The Project Designer must classify standing dead individuals according to the following decomposition classes, adapted from the document *Good practice guidance for land use, land-use change and forestry* by the IPCC.

a. Class 1: Corresponds to trees with preserved branches and twigs, maintaining architecture similar to living individuals, except for the absence of leaves.
b. Class 2: Corresponds to trees with clear signs of decomposition, in addition to leaf loss, including partial loss of twigs, branches, or the crown.

The biomass must be estimated according to its decomposition class (distinct from the dead wood density class):

a. Class 1:
    i. Use allometric equation or Biomass Conversion Expansion Factor (BCEF) applicable to living trees, assuming wood density equivalent to living individuals;
    ii. The BCEF value can be obtained from specific literature (by species, type of vegetation or region), according to the IPCC; or
    iii. empirically derived from local inventories, when total biomass and volume data are measured in sampled trees.
b. Class 2:
c. Only the biomass of the main trunk should be estimated, converting the volume into biomass using the corresponding dead wood density. The estimate of standing dead wood biomass stock is based on field measurements obtained in the same plots where aboveground biomass data will be collected, as per Section 9.1;
d. The Project Designer must determine the individual biomass of each standing dead tree recorded in the plot (pa) belonging to stratum (e);
e. The final value of the average standing dead wood biomass stock must be used to estimate the corresponding carbon stock, applying the biomass-to-carbon conversion factor as defined by the applicable methodology.

Fallen Dead Wood

a. The quantification of fallen dead wood must be carried out using the line intersection method, within the plot where aboveground biomass data will be collected;
b. The line interception method, including the location within the plot and the number of lines used, must be outlined, justified, and based on established technical protocols or peer-reviewed scientific articles.

c. The Project Designer must measure the trunk diameter (in cm) at the intersection point with the transect line and use this data to estimate the volume in ($m^3 . ha^{-1}$), according to Equation 28.

d. For each intercepted dead wood fragment, the diameter at the intersection point must be recorded and the degree of decomposition classified according to three standardized classes:

– Class 1: intact wood, with bark and preserved structure;

– Class 2: intermediate decomposition, without branches, with partial bark and firm wood;

– Class 3: advanced decomposition, without bark and with friable texture.

The class determination must be based on visual inspection and penetration resistance testing, as recommended by the *Good practice guidance for land use, land-use change and forestry* by the IPCC.

14.2. Biomass Quantification

Standing Dead Wood

To calculate the average biomass stock in standing dead trees present in the sample plot (*pa*) in stratum (e), Equation 27 must be applied:

$$B_{MM,P,pa,e} = \sum_{pa,e=1}^{Nºpa,e} \frac{B_{AM,P,pa,e}}{A_{pa}} \tag{27}$$

Where:

$B_{MM,P,pa,e}$= Standing dead wood biomass in the sampled plot in stratum “e” (t d.m.ha^{-1});

$B_{AM,P,pa,e}$= Biomass of each standing dead tree in the sampled plot in stratum “e” (t d.m.);

pa = Sampled plot;

e = stratum 1, 2, 3 .... n;

A_{pa}= Plot area (ha);

No. = Number of standing dead trees in the sampled plot pa of stratum e.

Fallen Dead Wood

The volume of fallen dead wood must be applied separately for each decomposition class according to Equation 28:

$$V_{MM,e} = \frac{(\sum Di^2)}{8 * L} \tag{28}$$

Where,

$V_{MM,,e}$= Volume of fallen wood in the decomposition class ($m^3.ha^{-1}$);

Di= Diameter measured at the intersection point with the transect (cm);

8 = Warren normalization factor, W. G; Olsen, P. F. (1964);

L= total transect length (m).

To determine the total fallen dead wood biomass in the stratum, the Project Designer must apply equation 29:

$$B_{MM,C,e} = \sum_{CD=1}^{CD} (V_{MM,e} * D_{MM\_CD}) \tag{29}$$

Where:

$B_{MM,C,e}$= Biomass of fallen dead wood in stratum “e” (t d.m. ha^{-1});

$V_{MM,e}$ = Volume of fallen wood in the decomposition class ($m^3.ha^{-1}$);

D_{MM_CD} = Average density of dead wood in density class CD (class 1 = intact wood; class 2 = intermediate decomposition; class 3 = advanced decomposition). (t d.m. m^{-3}).

CD = Density class of dead wood (class 1 = intact wood; class 2 = intermediate decomposition; class 3 = advanced decomposition).

Total Dead Wood

For the conversion of dead wood biomass into total average equivalent carbon stock, Equation 30 should be applied:

$$C_{MM,e} = \left(\left(B_{MM,P,e} + B_{MM,C,e}\right) * FC_{MS,MM}\right) * \frac{44}{12} \tag{30}$$

Where:

$C_{MM,e}$ = Average carbon stock stored in dead wood in stratum “e” (tCO_2e ha^{-1});

$B_{MM,P,e}$ = Biomass of standing dead wood in stratum “e” (t d.m. ha^{-1});

$B_{MM,C,e}$ = Biomass of fallen dead wood in stratum “e” (t d.m. ha^{-1});

$FC_{MS,MM}$ = Carbon fraction of dry matter in dead wood [tC $(t\ d.m.)^{-1}$] For projects in Brazil, use data from the National Communication. For projects outside Brazil, use IPCC data;

$\frac{44}{12}$ = Molecular conversion factor from carbon to carbon dioxide equivalent [tCO_2 $(tC)^{-1}$].

15. Wood Products

This section establishes the guidelines for quantifying carbon stocks in Harvested Wood Products, as defined in Section 1.

15.1. Data Collection

The Project Designer may use primary or secondary data. For each type of data adopted, the procedures for data collection, processing, and use must be properly outlined in the PDD.

For the collection of primary data, the Project Designer must ensure:

a. Direct estimation of the volume of wood extracted;

b. The estimate must be carried out following technical protocols from established institutions in the country and peer-reviewed.

The use of secondary data for the quantification of biophysical parameters and factors necessary for estimating carbon stocks and flows, including wood density, conversion factors, and carbon fraction, will be allowed, provided they come from recognized technical sources and are properly justified, according to the sources and hierarchy established in Section 7.1. In the absence of applicable data from these sources, for the quantification of carbon stocks in Harvested Wood Products, data from the following references may be used:

a. Production of Non-Timber Forest Products and Silviculture (PEVS), from the Brazilian Institute of Geography and Statistics (IBGE);

b. Databases and publications from the National Institute for Amazonian Research (INPA);

c. Publications, databases, and technical studies from Embrapa;

d. *Global Wood Density Database* (FISCHER, F.J. et al, 2026);

e. IPCC standard parameters;

f. International statistics of forest products from the *Food and Agriculture Organization* (FAO).

The methodology used for data collection, processing, and analysis must be properly documented, including the justification for the choice of sources and parameters used.

15.2. Biomass Quantification

When the Project Designer has an approved forest management or timber harvesting plan for the Project Area, containing the exploitation intensity per stratum expressed as the volume of wood extracted per hectare, the calculation of the carbon stock must be carried out according to Equation 31.

$$C_{PMb\text{ClsPM},,e} = \frac{1}{A_{total,e}} * \sum_{Ea=0}^{Ea} V_{PM,Ea,h,e} * D_{Ea} * FC_{Ea} * \frac{44}{12} \quad (31)$$

Where:

$C_{PMb,\text{ClsPM},e}$ = Average gross carbon stock stored per harvested wood product class in stratum “e” (tCO_2e ha^{-1});

$V_{PM,Ea,h,e}$ = Commercial volume of wood extracted from stratum “e” by species and harvested wood product class (m^3);

$A_{total,e}$ = Total area of stratum "e" (ha);

D_{Ea} = Average wood density of the species (t d.m. m^{-3});

FC_{Ea} = Carbon fraction of biomass for the tree species [tC (t d.m.)$^{-1}$]. For projects in Brazil, use data from the National Communication. For projects outside Brazil, use IPCC data;

Ea = 1, 2, 3,... tree species;

e = Stratum 1, 2, 3 .... n;

ClsPM = harvested wood product class, such as sawn wood, wood-based panels, industrial roundwood, pulp, charcoal, firewood, among others;

$\frac{44}{12}$ = Molecular conversion factor from carbon to carbon dioxide equivalent [tCO_2 (tC)$^{-1}$].

In the absence of approved forest management or timber harvesting plans or available information for the Project Area related to aboveground biomass stock, the average carbon stock associated with harvested wood products must be estimated according to Equation 32, in accordance with the guidelines established in the applied methodology.

$$C_{PMb,\mathrm{ClsPM},e} = C_{BAc,e} * \frac{1}{FCEB} * F_{MC,e} \tag{32}$$

Where:

$C_{PMb,\mathrm{ClsPM},e}$ = Average gross carbon stock stored per harvested wood product class in stratum "e" (tCO_2e ha^{-1});

$C_{BAc,e}$ = Average carbon stock stored in aboveground biomass in stratum "e" (tCO_2e ha^{-1});

$FCEB$ = Biomass conversion and expansion factor (Dimensionless). Factor used to convert the commercial volume of wood per unit area into total aboveground tree biomass per unit area and to estimate the proportion of forest biomass with potential for use in harvested wood products. It should be obtained from literature data, following the guidelines in Section 15.1;

$F_{MC,e}$ = Total commercial volume of aboveground biomass in stratum "e" (%). Factor used to estimate the proportion of biomass with potential for use in harvested wood products that will actually be destined for the production of harvested wood products. It should be obtained from published data, following the guidelines in Section 15.1;

ClsPM = harvested wood product class, such as sawn wood, wood-based panels, industrial roundwood, pulp, charcoal, firewood, among others;

e = stratum 1, 2, 3 .... n.

The volume of wood extracted that becomes waste during industrial processing is not incorporated into the harvested wood products pool, as this material is considered emissive, resulting from losses due to inefficiency in the conversion process. To obtain the value of the net carbon stock for each harvested wood product class, the Project Designer must apply equation 33:

$$C_{PM,\mathrm{ClsPM},e} = C_{PMb,\mathrm{ClsPM},e} * (1 - RM_{\mathrm{ClsPM},e}) \tag{33}$$

Where:

$C_{PM,\mathrm{ClsPM},e}$ = Net carbon stock stored per harvested wood product class in stratum "e" (tCO_2e ha^{-1});

$C_{PMb,\mathrm{ClsPM},e}$ = Average gross carbon stock stored per harvested wood product class in stratum “e” (tCO_2e ha^{-1});

$RM_{\mathrm{ClsPM},e}$ = Fraction of carbon emitted as waste generated during industrial wood processing, by harvested wood product class in stratum “e” (Dimensionless);

ClsPM = harvested wood product class, such as sawn wood, wood-based panels, industrial roundwood, pulp, charcoal, firewood, among others;

e = stratum 1, 2, 3 .... n.

After obtaining the value of the net carbon stock for each harvested wood product class, the Project Designer must classify the harvested wood product classes (ClsPM) according to their durability and decomposition dynamics, according to the following categories:

a. Short-duration fraction: products that release CO_2 to the atmosphere instantly in year t_d, due to rapid decomposition or burning of these materials, such as harvest residues, firewood, charcoal, and other products with instant CO_2 release to the atmosphere (h = 1);
b. Medium-term fraction: products that release CO_2 gradually over a period of 20 years, through a linear decay, with emissions distributed evenly between years t_d and t_d + 19, such as sawn wood, panels, furniture, and other products used in temporary applications (h = 20);
c. Long-term fraction: products that release CO_2 into the atmosphere after a period of 20 years, such as wooden structures in buildings, bridges, and other constructive wood products with use exceeding the temporal analysis horizon (h = >20).

The Project Designer must use Equation 34 to calculate the sum of the net carbon stock of each class of wood product in the analyzed time horizon.

$$C_{PM,h,e} = \sum_{\mathrm{ClsPM}=0}^{\mathrm{ClsPM}} C_{PM,\mathrm{ClsPM},e} \quad (34)$$

Where:

$C_{PM,h,e}$ = Net carbon stock stored in the classes of wood products in the time horizon of CO_2 release analyzed in stratum “e” (tCO_2e ha^{-1});

$C_{PM,\mathrm{ClsPM},e}$ = Net carbon stock stored per harvested wood product class in stratum “e” (tCO_2e ha^{-1});

h = Time horizon for CO_2 release into the atmosphere (1, 20 or >20);

ClsPM = class of wood product, such as sawn wood, wood-based panels, constructive wood products, pulp, charcoal, firewood, among others;

e = stratum 1, 2, 3 .... n.

The total net carbon stock of Wood Products must be obtained according to equation 35:

$$C_{PM,e} = \sum_{h=0}^{h} C_{PM,h,e} \quad (35)$$

Where:

$C_{PM,e}$ = Sum of the net carbon stock stored in all time horizons of CO_2 release analyzed in stratum "e" ($tCO_2e\ ha^{-1}$);

$C_{PM,h,e}$ = Sum of the net carbon stock stored in the classes of wood products in the time horizon of CO_2 release analyzed in stratum "e" ($tCO_2e\ ha^{-1}$);

h = Time horizon for CO_2 release into the atmosphere (1, 20 or >20);

e = stratum 1, 2, 3 .... n.

16. Requirements for the Application of Equations

If the Project Designer proposes the use of allometric equations, such equations may be accepted provided they meet the guidelines (as per Section 7) and the technical requirements established in this section.

The equations used by the Project Designer must follow the following guidelines:

a. They must be equations validated for the region and for the vegetation type corresponding to the Project Area;
b. For biomass estimates of bamboos, vines, tree ferns, and palms, specific equations compatible with the morphology of these formations must be used, when their inclusion is adopted by the Project Designer;
c. Species-specific equations must be generated based on data from at least 10 individuals;
d. Present a coefficient of determination (R^2 or adjusted R^2) equal to or greater than 0.7.

The choice of reference sources for the equations must follow the following order of prioritization:

a. Local or regional equations, published and peer-reviewed;
b. National inventories, published by research institutions recognized by the country's government;
c. IPCC equations;
d. Equations authored by the Project Designer, provided they are published and peer-reviewed.

For each equation used, the Project Designer must present, at a minimum:

a. The parameters used in the equations;
b. The coefficient of determination (R^2 or adjusted R^2);
c. The standard error of the estimate (Syx);
d. The root mean square error (RMSE); and
e. Graphical analysis of the residuals.

16.1. Soil Organic Carbon

For the estimation of soil organic carbon (SOC), the Project Designer must use empirical stock calculation equations, based on direct laboratory measurements of organic carbon content, bulk density of the soil, and the depth of the sampled layer.

With respect to methodological procedures, the Project Designer must present:

a. Description of the quality and integrity of the samples collected;
b. Description of the accuracy of laboratory analyses;
c. Proof of instrument calibration;
d. Demonstration of the spatial representativeness of the samples;
e. Methodological suggestions are available in:
    i. IPCC 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF);
    ii. Nelson, D.W., and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. p. 539–580. In A.L. Page et al. (ed.) Methods of Soil Analysis. Part 2. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

iii. Pearson, T., Walker, S. and Brown, S. 2005. Sourcebook for Land Use, Land-Use Change and Forestry Projects. Winrock International and World Bank Biocarbon Fund. 57pp.

17. Uncertainties

The Project Designer must identify, quantify, and conservatively document the main sources of uncertainties associated with carbon stock estimates, in accordance with the guidelines of the ECORA Carbon Credit Certification Program Standard and MOEC002 – Uncertainty Quantification Module.

The Project Designer must calculate the percentage of uncertainty associated with the carbon stock for each reservoir included in the Baseline Scenario and in the Project Scenario and present the results in the PDD and Monitoring Reports (MR).

For this, the Project Designer must consider, but not be limited to, the following sources of uncertainty:

a. Sources of uncertainty required for all carbon reservoirs:
   i. Sampling design;
   ii. Error in biomass density estimation;
   iii. Errors in the measurement of dendrometric variables;
   iv. Inaccuracies in sample collection;
   v. Uncertainty associated with laboratory procedures;
   vi. Error in spatial extrapolation of data;
   vii. Use of regional rather than local data;
   viii. ALS measurement errors;
   ix. Uncertainty associated with statistical modeling;
   x. Uncertainty associated with the equations used.
b. Specific source of uncertainty for the Wood Products reservoir:
   i. Loss factors during processing;
   ii. Short and long life fractions;
   iii. Assumptions about disposal;
   iv. Oxidation and degradation rates after use;
   v. Assumption that the carbon remaining after 100 years is considered permanent;
   vi. Application of fixed factors that may not reflect sectoral variations.
c. Source of uncertainty specifications for soil organic carbon for projects where quantification is mandatory:
   i. It is recommended that soil organic carbon analyses by dry combustion be conducted in laboratories accredited according to internationally recognized quality management standards, such as ISO/IEC 17025;
   ii. Laboratories must provide:
      - Traceability and complete documentation of the analytical methods employed, equipment used, and calibration procedures;
      - Validated dry combustion methods for determining total and organic soil carbon content;
   iii. The use of non-accredited laboratories is permitted, provided that the Project Designer demonstrates evidence of traceability, calibration, and internal quality control equivalent to the ISO/IEC 17025 standard

iv. The calculation of uncertainty associated with SOC or ∆SOC estimates must include, at a minimum:

- Sample variability;
- Model errors;
- Uncertainties associated with the sampling process and laboratory analyses;

v. Estimates of SOC stock and/or variation, their respective variances, and the uncertainty discount mechanisms applied must be presented clearly and documented.

18. Evidence

The provision of this evidence is exclusively for guidance and not exhaustive; therefore, the list provided aims to assist Project Designers in organizing submissions, but does not guarantee that all requirements applicable to the specificities of the Project (regional and local) are covered. It is entirely the responsibility of the Project Designer to ensure that the evidence relevant to the quantification of carbon stocks and compliance with the certification program standards is submitted for analysis.

The Project Designer may use, but is not limited to, the following information as documentary and descriptive evidence in the PDD:

a. Manual or field method followed for sampling procedures, duly cited so as to be accessible for consultation;

b. Description of field plots and subplots and/or collection points;

c. Georeferenced file of plots and subplots and/or collection points;

d. Include photographic records and field sheets with collection conditions;

e. Description of materials and equipment used in the data collection stages, including at a minimum the name, year, equipment model, relevant technical specifications, and operational conditions;

f. When there is soil analysis, include results of replicates, controls, and reference materials used;

g. Description of the soil sample preparation procedure, including drying, sieving, and homogenization;

h. Description of the sources, models, and parameters used in the data evaluation, including the equations employed, their respective justifications for selection, bibliographic references, selection criteria, and adjustments or calibrations performed;

i. Scripts used for estimates and/or statistical analyses;

j. Industrial transformation and useful life factors: justifications and references for industrial loss factors, useful life fraction, and oxidation factor compatible with the product type and regional reality, when applicable.

k. Reference source of the adopted conversion factor(s);

l. Studies that supported the equations used;

m. Calculation spreadsheets with means, standard deviations, and coefficients of variation for each carbon reservoir, by stratum. It should be noted that for the purposes of calculating the acceptable error, the confidence level adopted is 90%, according to MOEC002 – Module for Quantification of Uncertainties. If the value falls below 90%, the Project Designer must adopt adjustments in the sampling design or in the data collection and analysis procedures to meet the minimum required value. Representativeness and sampling error must have their application made explicit based on materiality and/or a tiered approach, allowing technical justifications when, individually, they present high variability and disproportionate cost;

n. The measurement procedures must contain a Data Quality Management and Control Plan (QMCP), as indicated by the methodology used, when applicable.

When Soil Organic Carbon is required by the methodology, the Project Designer must include, in addition to the items in Section 7, the following information:

a. The calibration of the models should preferably be carried out with data obtained in the Project Area or, when not available, in areas with similar edaphoclimatic and management conditions;

b. The developer must provide the name, location, and accreditation of the laboratory responsible for the analyses;

c. The analytical method used must be specified;

d. If the laboratory does not have ISO/IEC 17025 accreditation, equivalent evidence of traceability (equipment calibration certificate, standardized operating procedure, analytical quality control record, participation in proficiency tests, technical quality of the team, equipment maintenance and verification records, and documentation of the sample chain of custody) and a Data Quality Management and Control Plan (QMCP) must be provided.

When data obtained by remote sensing are used, the Project Designer must include, in addition to the Item in Section 7, the following information:

a. Justification of the predictor variables considered and the choice of the model;

b. Definition of the architecture or algorithm used, describing its main parameters, training procedures, and the criteria used to evaluate the model's performance;

c. Minimum operational parameters of the aerial survey: flight altitude and speed, sensor angular aperture, pulse frequency (PRF), scan rate, and swath width;

d. Scripts, parameters, and software versions used in image processing and modeling.

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Appendix A: Laboratory methods for the determination of soil organic carbon in soil samples

For the quantification of the total soil organic carbon parameter used in field quantification procedures and calibration of the use of remote field sensors and analytical instruments based on spectroscopy (e.g., NIR or MIR), one of the following laboratory determination methods should be considered:

a. Dry combustion in an elemental analyzer (CHN);

b. Complete oxidation of soil organic matter at temperatures above 900 ºC, converting organic carbon into CO_2 for detection by the analyzer;

c. Quantification of the concentration of CO_2 determined by non-dispersive infrared detection;

d. Analytical instruments based on spectroscopy (e.g., NIR or MIR);

e. Recording of results expressed in g C hg^{-1} of dry soil.

f. The use of the Walkley-Black (wet oxidation) and loss on ignition (LOI) methods should not be used, due to precision limitations. The application of the Walkley-Black and LOI methods will only be accepted on an exceptional basis, with duly documented technical justification, and only when more suitable alternative methods are not available. This technical justification must be evaluated by the VVB during the project's Validation and Verification audits.

g. The Project Designer may use remote field sensing and analytical instruments based on spectroscopy (e.g., NIR or MIR) for the determination of soil organic carbon, provided that consistent calibration and validation models are employed, with analytically proven performance equivalent to the standard method.

h. Field data collection for model calibration must follow the same parameters and requirements described in section 11.1, and must additionally include:

i. The calibration curve used to adjust the model;

j. The parameters used in the model, such as the coefficient of determination (R^2 or adjusted R^2), the standard error of estimate (Syx), the root mean square error (RMSE), and the graphical analysis of residuals.

k. The validation statistics, including as a minimum criterion, coefficient of determination R2 > 0.8 and root mean square error (RMSE) < 10%, with the possibility of adopting a contextual approach (by biome/stratum and sampling design), allowing for a higher RMSE when technically justified, provided it is accompanied by additional requirements such as independent validation, sufficient sampling, uncertainty reporting, and safeguards against bias.