# ECORA Carbon Credit Certification Program

Document: MOEC003 – Greenhouse Gas Emissions Quantification and Carbon Stock Reduction Module

Public Consultation Stage

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# 1. Acronyms and Definitions

| Term | Definition |
|---|---|
| Aboveground Woody Biomass | Includes all living biomass from aboveground vegetation that has a lignified stem structure, which, for this methodology, includes trees and shrubs. Bamboos and palms will also be accounted for, provided they have their own biomass estimation method. |
| Agriculture, Forestry and Other Land Use (AFOLU) | The sector defined by the IPCC that brings together Agriculture, Forestry, and Other Land Use activities used in the accounting of emission reductions or GHG removals. |
| Carbon Dioxide ($CO_2$) | A greenhouse gas naturally present in the atmosphere, composed of one carbon atom and two oxygen atoms, which absorbs and re-emits infrared radiation, influencing the Earth's radiative balance. It is emitted by natural processes and by anthropogenic activities, such as the combustion of fossil fuels, land use changes, and industrial processes. |
| Dead Wood | Corresponds to the carbon stock contained in dead woody components located aboveground, including standing dead trees, trunks, branches, and fallen wood fragments with a diameter equal to or greater than the methodologically defined limit. |
| Extraction Trails | Temporary linear strips opened within the area under forest management, intended for the movement and dragging of logs from the felling site to storage yards or main roads, established within the scope of a Sustainable Forest Management Plan, in accordance with technical guidelines from IBAMA, the Brazilian Forest Service, and the competent environmental agencies. |
| Fossil Fuel | An energy resource of geological origin, formed from the decomposition and transformation of organic matter over millions of years, composed predominantly of carbon and hydrogen, whose combustion releases energy and results in the emission of carbon dioxide ($CO_2$) and other greenhouse gases into the atmosphere. |
| Global Warming Potential (GWP) | As defined by ISO 14064-1:2018: An index, based on the radiative properties of Greenhouse Gases (GHG), that measures the radiative forcing resulting from an instantaneous emission of a unit mass of a given GHG in the current atmosphere, integrated over a chosen time horizon, relative to carbon dioxide. |
| Greenhouse Gases (GHG) | Greenhouse gases as defined by ISO 140641:2018: “gaseous component of the natural or anthropogenic atmosphere, which absorbs and emits radiation at |

| Term | Definition |
| --- | --- |
| | specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds.”<br><br>The following are considered GHGs: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride ($SF_6$), and nitrogen trifluoride ($NF_3$). |
| Litterfall | Corresponds to the carbon stock present in the layer of newly deposited organic material on the soil, composed of leaves, fine branches, fruits, flowers, and other plant debris at different initial stages of decomposition. This reservoir represents the transient fraction of ecosystem carbon, located above the soil surface and below the living vegetation. |
| Logging Gaps | Areas of temporary opening of the forest canopy resulting from the felling, processing, and movement of trees during logging operations under a Sustainable Forest Management Plan. |
| Methane ($CH_4$) | A greenhouse gas naturally present in the atmosphere, composed of one carbon atom and four hydrogen atoms, which absorbs and re-emits infrared radiation, influencing the Earth's radiative balance. It is emitted by natural processes and by anthropogenic activities, such as the anaerobic decomposition of organic matter, enteric fermentation of ruminants, waste management, and the production and transportation of fossil fuels. |
| Net Calorific Value (NCV) | Net calorific value as defined by ANP Resolution No. 40/2013 (and subsequent resolutions that replace or complement it) “is the amount of energy released by the complete combustion of a fuel, disregarding the energy associated with the condensation of water vapor formed during combustion, expressed per unit of mass or volume, and used to estimate the energy content effectively available for energy generation.” |
| Nitrogen Volatilization | A process by which nitrogen applied to the soil, mainly in the form of ammonia ($NH_3$) or ammoniacal compounds, is converted into a gaseous form and released into the atmosphere, influencing the availability of nitrogen in the soil and indirectly contributing to greenhouse gas emissions, such as $N_2O$. |
| Nitrous Oxide ($N_2O$) | A greenhouse gas naturally present in the atmosphere, composed of two nitrogen atoms and one oxygen atom, which absorbs and re-emits infrared radiation, influencing the Earth's radiative balance. It is emitted by natural processes and by anthropogenic activities, especially those associated with the use of nitrogen fertilizers, |

| Term | Definition |
|---|---|
| | agricultural soil management, biomass burning, and industrial processes. |
| Storage Yards | Open and generally leveled areas, temporarily established inside or on the periphery of the area under forest management, to be used for the concentration, organization, measurement, and temporary storage of forest products, especially logs, prior to transport, in accordance with technical guidelines from IBAMA, the Brazilian Forest Service, and the competent environmental agencies. |
| Sustainable Forest Management | Sustainable forest management as defined by the Brazilian Forest Code Art. 3, item VII:<br><br>"*management of natural vegetation to obtain economic, social, and environmental benefits, respecting the support mechanisms of the ecosystem subject to management and considering, cumulatively or alternatively, the use of multiple timber or non-timber species, multiple products and by-products of the flora, as well as the use of other goods and services*." |
| Wood Products | Corresponds to the carbon stock retained in products derived from extracted woody biomass, including sawn wood, plywood, panels, paper, and other forest-based products with different lifespans, representing the carbon transferred from forest biomass to products stored outside the ecosystem. |

# 2. Introduction

This module establishes guidelines for the quantification of greenhouse gas (GHG) emissions and reductions in carbon stocks in Agriculture, Forestry, and Other Land Use (AFOLU) projects, covering emissions from biomass burning, $N_2O$ emissions associated with the application of nitrogen fertilizers and liming, emissions from fossil fuel consumption by machinery, as well as reductions in carbon stocks resulting from sustainable forest management activities.

This document consists of seven sections, namely: (1) *Acronyms and Definitions*, which presents the technical terms, concepts, and acronyms used throughout the document; (2) *Introduction*, which provides context for the Greenhouse Gas Emissions Quantification and Carbon Stock Reduction Module for AFOLU Projects and its objectives; (3) *Applicability*, which defines the scope of use of the tool, those responsible for its application, and the times at which assessments should be conducted; (4) *Biomass Burning,* which describes the greenhouse gases considered and details the procedures for quantifying emissions generated by biomass burning, including approaches for estimating and accounting for associated emissions; (5) *$N_2O$ Emissions from Nitrogen Fertilizers and Liming,* which describes the parameters and procedures for quantifying $N_2O$ emissions associated with the use of nitrogen fertilizers and liming, including the determination of applied nitrogen, the estimation of total emissions, as well as the accounting of direct and indirect emissions resulting from these practices; (6) *Fossil Fuels and Machinery*, which addresses the identification of emission sources associated with the use of fossil fuels in machinery, the calculation of total emissions resulting from fuel consumption, and procedures for estimating consumption in the absence of direct measurements; and (7) *Sustainable Forest Management*, which describes activities related to sustainable forest management that may result in the reduction or loss of carbon stocks, including the characterization of these activities and the quantification of reductions associated with the clearing of logging sites and the implementation and operation of logging infrastructure.

# 3. Applicability

The Greenhouse Gas (GHG) Emissions Quantification and Carbon Stock Reduction Module is applicable to projects in the AFOLU sector, with the aim of contributing to consistent and transparent estimates aligned with recognized methodological guidelines. Additionally, indices, parameters, or emission factors from regional or specific sources may be used, provided they are accompanied by technical justification and evidence demonstrating their compatibility with official sources and national reference data. The adoption of this data and these methods will be subject to analysis and approval by the ECORA Carbon Credit Certification Program and the Validation and Verification Bodies (VVB), in order to maintain compliance with applicable methodological requirements.

The calculations provided for in this module will be progressively integrated into ECORA's digital project development platform. On the platform, emission estimates will be automatically generated from the online entry of the required data and parameters by the Project Designer. The calculation record used by the digital platform will make the specifications used in the calculation’s public in an auditable manner and with change control between module versions. When updating calculation record versions, the changes made between versions will be specified in a transparent and auditable manner. Additionally, guidance will be provided on the procedures applicable to projects as a result of the implemented modifications.

The Project Designer must perform the cumulative sum of the contributions of GHG emissions and carbon stock reductions addressed in the topics of this module, starting with the largest values, until reaching at least 95% of the project's total net GHG emissions. Elements not included in the cumulative sum may be considered immaterial when their aggregate contribution is less than 5%[1] of the total GHG emissions of the project activity, provided that such exclusion does not compromise the representativeness, completeness, and accuracy of GHG emissions in the Project Scenario. In these cases, the justification for classifying emissions as immaterial must be documented and presented to the VVB during the Validation and/or Verification processes. If there are combined GHG emission sources whose aggregate contribution exceeds 5% of total emissions, these must be included as net GHG emissions in the Project Scenario.

[1] According to the CDM tool (EB 31, *Tool for testing significance of GHG emissions in A/R CDM project activities*, Version 01), emissions whose sum is less than 5% of the total decreases in carbon reservoirs and increases in emissions, or less than 5% of net anthropogenic removals by sinks, whichever is lower, are considered insignificant and may be neglected. This procedure, based on the analysis of key categories from the IPCC, uses a cumulative threshold of 95% to identify significant sources, defining sources outside this sum as insignificant, provided they meet the criterion of participation below 5% in the total result. Therefore, the 5% criterion was adopted as the materiality threshold for the exclusion of emission sources from this project.

# 4. Biomass Burning

## 4.1 Greenhouse Gases Accounted For

For the purpose of estimating greenhouse gas (GHG) emissions associated with biomass burning, the Project Designer must account for methane ($CH_4$) and nitrous oxide ($N_2O$) emissions, as these are the greenhouse gases generated by biomass combustion in the context of the AFOLU sector.

Carbon dioxide ($CO_2$) emissions should not be accounted for in the calculation of emissions from biomass burning. This is because the $CO_2$ released in this process is already accounted for by the change in carbon stocks (living biomass, dead organic matter, and soils), reflecting the net $CO_2e$ balance of the system. Exceptionally, the emission of $CO_2$ gas may be accounted for in the emissions calculation as biomass burning only when there is an explicit requirement from the applied methodology. In such cases, it must be demonstrated that there is no overlap with the accounting of carbon stock changes. The selection of greenhouse gases accounted for must comply with the *Guidelines for National Greenhouse Gas Inventories* of the IPCC (2006 and 2019 refinements), hereinafter IPCC.

The set of gases considered as emissions from biomass burning must be applied throughout the project's crediting period. The inclusion, exclusion, or selective alteration of accounted GHGs between monitoring periods is not allowed, unless explicitly required by regulatory updates or by revision of the applied methodology.

## 4.2 Quantification of Emissions Generated by Biomass Burning

The structure of variables used for quantifying GHG emissions resulting from biomass burning is set out sequentially in Figure 1. Emissions generated by biomass burning are quantified and reported in units of metric tons of carbon dioxide equivalent ($tCO_2e$).

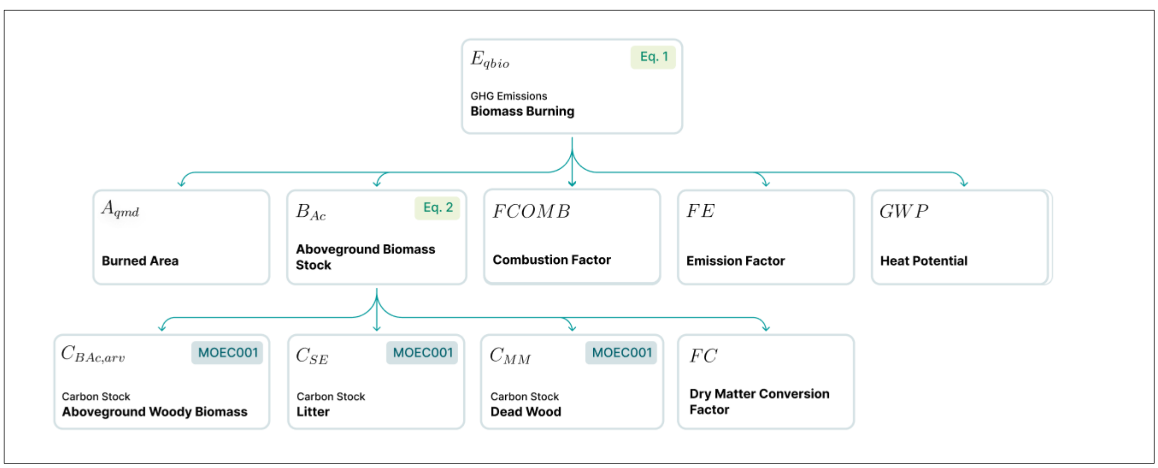


**Figure 1. Flowchart of equations for quantifying greenhouse gas emissions from biomass burning.**

The estimate of greenhouse gas emissions from biomass burning must be determined according to Equation 1:

$$E_{qbio,e,t} = \sum_{g=1}^{G}(((A_{qmd,e,t} * B_{Ac,mda,e,t} * FCOMB_e * FE_{g,e}) * 10^{-3}) * GWP_g) \quad (1)$$

Where:

$E_{qbio,e,t}$ = GHG emissions due to biomass burning in stratum "e" in year "t" for each GHG ($CH_4$ and $N_2O$) ($tCO_2e$);

$A_{qmd,e,t}$ = Burned area in stratum "e" in year "t" (ha);

$B_{Ac,mda\ e,t}$ = Average aboveground woody biomass before burning in stratum "e" in year "t" [t of dry matter $(ha)^{-1}$];

$FCOMB_e$ = Combustion factor for stratum "e";

$FE_{g,e}$ = Emission factor for gas "g" in stratum "e" [kg $(\text{t of dry matter burned})^{-1}$];

$GWP_g$ = Global warming potential for gas "g" [$tCO_2e$ $(\text{t gas g})^{-1}$];

$10^{-3}$ = Used to convert gas mass units from kg to metric ton;

g = Greenhouse gases;

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

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

For the values of the combustion factor for stratum "e" ($FCOMB_e$) and the emission factor for gas g in stratum "e" ($FE_{g,e}$), the values from Table 2.5 of the IPCC (2006, Volume 4, Chapter 2) should be used. These values should be updated as new guidelines or refinements are published by the IPCC.

The average amount of aboveground biomass before burning for a given stratum is estimated using Equation 2:

$$\mathrm{B}_{Ac,mda,e,t} = (C_{BAc,arv,e,t} + C_{MM,e,t} + C_{SE,e,t}) * \frac{12}{44} * \left(\frac{1}{\mathrm{FC}}\right) \quad (2)$$

Where:

$\mathrm{B}_{Ac,mda,e,t}$ = Average aboveground biomass before burning in stratum "e" in year "t" [t of dry matter $(ha)^{-1}$];

$C_{BAc,avr,e,t}$ = Carbon stock stored in aboveground woody biomass in trees in stratum "e" in year "t" ($tCO_2e$ $ha^{-1}$);

$C_{MM,e,t}$ = Carbon stock stored in dead wood in stratum "e" in year "t" ($tCO_2e$ $ha^{-1}$);

$C_{SE,e,t}$ = Carbon stock stored in litter in stratum "e" in year "t" ($tCO_2e$ $ha^{-1}$);

$\frac{12}{44}$ = Inverse ratio between the molecular weight of $CO_2$ and that of carbon [$tCO_2e$ $(\text{t C})^{-1}$];

$\frac{1}{\mathrm{FC}}$ = Inverse ratio between the conversion factor of dry matter to carbon [t C $(\text{t dry matter})^{-1}$];

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

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

The Project Designer must use the IPCC default values for the dry matter to carbon conversion factor ($\mathrm{FC}$), as demonstrated in Table 4.3 of the IPCC (2006, Volume 4, Chapter 4). These values should be updated as new guidelines or refinements are published by the IPCC.

The values of carbon stock stored in aboveground woody biomass in trees in stratum “e” ($C_{BAc,arv,e,t}$), carbon stock stored in dead wood in stratum “e” ($C_{MM,e,t}$) and carbon stock stored in litter in stratum “e” ($C_{SE,e,t}$), must be the same as those reported in the Project Verification, obtained from the results of applying MOEC001: Carbon Measurement in Vegetation Module. If the dead wood and litter pools are not accounted for in the Project Scenario, they must be excluded from the biomass burning calculations.

# 5. Emissions of $N_2O$ from Nitrogen Fertilizers and Liming

## 5.1 Applied Nitrogen

Emissions of nitrous oxide ($N_2O$), related to the Baseline and Project Scenarios, including direct and indirect emissions, are quantified and reported in units of metric tons of carbon dioxide equivalent ($tCO_2e$).

The estimated emissions for the Baseline and Project Scenarios are calculated on an annual basis and normalized per unit area, per hectare (ha).

For accounting purposes, year $t_{12}$ corresponds to a continuous period of 12 (twelve) months following the first application of nitrogen fertilizer associated with crops implemented within the project boundaries.

The calculation of direct and indirect $N_2O$ emissions follows the terminology, concepts, and methodological justifications established in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, contributing to consistency, transparency, and comparability with national inventories and with the standards adopted by carbon credit certification programs.

### 5.1.1 Total emissions of $N_2O$ from the use of nitrogen fertilizers

The methodological framework for quantifying $N_2O$ emissions from the application of nitrogen fertilizers and liming is presented in Figure 2, which sequentially organizes the main variables involved in the calculation, including total $N_2O$ emissions resulting from nitrogen application, direct emissions associated with the use of synthetic and organic nitrogen fertilizers, as well as indirect $N_2O$ emissions resulting from volatilization and leaching losses.

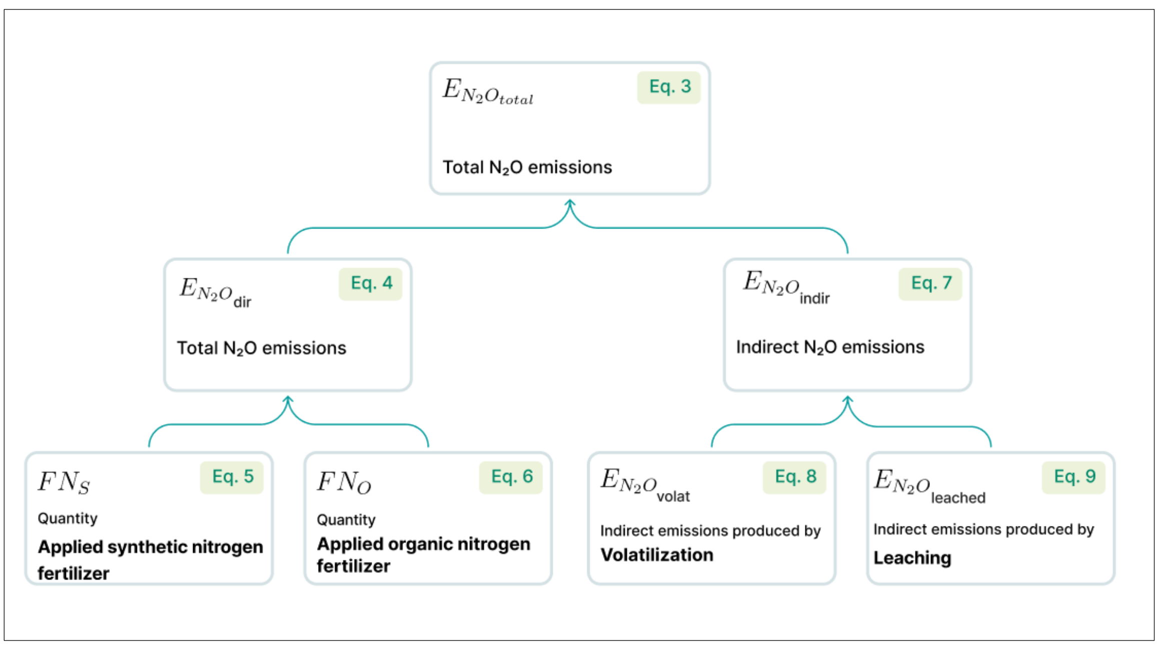


**Figure 2. Flowchart showing the equations for quantifying $N_2O$ emissions from the application of nitrogen fertilizers.**

Total nitrous oxide emissions from nitrogen fertilization should be estimated using Equation 3 as follows:

$$E_{\mathrm{N_2O}_{total,e,t12}} = E_{\mathrm{N_2O}_{dir,e,t12}} + E_{\mathrm{N_2O}_{indir,e,t12}} \quad (3)$$

Where:

$E_{\mathrm{N_2O}_{total,e,t12}}$ = Total $N_2O$ emissions resulting from nitrogen application in stratum "e" in year "$t_{12}$" [$tCO_2e$ (ha year)$^{-1}$];

$E_{\mathrm{N_2O}_{dir,t12}}$= Direct $N_2O$ emissions from the Project Area in stratum "e" in year "$t_{12}$" [$tCO_2e$ (ha year)$^{-1}$];

$E_{\mathrm{N_2O}_{indir,t12}}$ = Indirect $N_2O$ emissions from the Project Area in stratum "e" in year "$t_{12}$" [$tCO_2e$ (ha year)$^{-1}$]);

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

$t_{12}$ = Continuous period of 12 (twelve) months following the first application of nitrogen fertilizer.

### 5.1.2 Direct emissions of $N_2O$ from the use of nitrogen fertilizers

Direct emissions of nitrous oxide ($N_2O$) associated with the application of nitrogen fertilizers to the soil should be estimated considering all relevant sources of nitrogen applied within the project boundaries. For calculation purposes, both synthetic and organic fertilizers should be included, when applicable in the project areas. The quantification of emissions must follow the procedures, emission factors, and methodological assumptions established in the IPCC Guidelines, ensuring methodological consistency between the Baseline and Project Scenarios.

For the calculation of direct emissions, Equation 4 should be used:

$$E_{\mathrm{N_2O}_{dir,e,t12}} = (FN_{S,t12} + FN_{O,t12}) * FE_{ED} * \frac{44}{28} * \mathrm{N_2O}_{GWP} \quad (4)$$

Where:

$E_{\mathrm{N_2O}_{dir,e,t12}}$= Direct $N_2O$ emissions from the Project Area in stratum "e" year "$t_{12}$" [$tCO_2e$ (ha year)$^{-1}$]);

$FN_{S,t12}$ = Synthetic nitrogen fertilizer applied in year "$t_{12}$" [t N (ha year)$^{-1}$];

$FN_{O,t12}$ = Organic nitrogen fertilizer applied in year "$t_{12}$" [t N (ha year)$^{-1}$];

$FE_{ED}$ = Emission factor for direct $N_2O$ emissions from N inputs Mg $N_2O$ – N (t N inputs)$^{-1}$;

$\frac{44}{28}$ = Ratio between the molecular weight of $N_2O$ and N [t $N_2O$ (t N)]$^{-1}$;

$\mathrm{N_2O}_{GWP}$ = Global warming potential for $N_2O$ [$tCO_2e$ (t $N_2O$)$^{-1}$];

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

$t_{12}$ = Continuous period of 12 (twelve) months following the first application of nitrogen fertilizer.

For the values of the emission factor for direct $N_2O$ emissions from N inputs Mg $N_2O$–N ($FE_{ED}$), the value to be adopted should be verified in Table 11.1 in the IPCC guidelines (2006, Volume 4, Chapter 11), and these values should be updated as new guidelines or refinements are published by the IPCC.

The synthetic nitrogen fertilizer applied should be calculated using Equation 5:

$$FN_{S,t12} = MFN_{S,t12} * N_{FS} \quad (5)$$

Where:

$FN_{S,t12}$ = Synthetic nitrogen fertilizer applied in year "$t_{12}$" [t N(ha year)$^{-1}$];

$MFN_{S,t12}$ = Mass of synthetic nitrogen fertilizer applied in year "$t_{12}$" [t (ha year)$^{-1}$];

$N_{FS}$ = N content of the synthetic fertilizer applied [g N (100g fertilizer)$^{-1}$];

$t_{12}$ = Continuous period of 12 (twelve) months following the first application of nitrogen fertilizer.

The organic nitrogen fertilizer applied should be calculated using Equation 6:

$$FN_{O,t12} = MFN_{O,t12} * N_{FO} \quad (6)$$

Where:

$FN_{O,t12}$ = Organic nitrogen fertilizer applied in year "$t_{12}$" [t N(ha year)$^{-1}$];

$MFN_{O,t12}$ = Mass of organic nitrogen fertilizer applied in year "$t_{12}$" [t (ha year)$^{-1}$];

$N_{FO}$ = N content of the organic fertilizer applied [g N (100g fertilizer)$^{-1}$];

$t_{12}$ = Continuous period of 12 (twelve) months following the first application of nitrogen fertilizer.

### 5.1.3 Indirect emissions of $N_2O$ from the use of nitrogen fertilizers

Indirect emissions of nitrous oxide ($N_2O$) resulting from the application of nitrogen fertilizers must be estimated considering the nitrogen losses that occur outside the application site. For calculation purposes, the following must be included: (i) emissions of $N_2O$ resulting from the volatilization of nitrogen in the form of ammonia ($NH_3$) and nitrogen oxides ($NO_x$), subsequently deposited on soils and bodies of water; and (ii) emissions of $N_2O$ associated with nitrogen lost through leaching and surface runoff. The quantification of these emissions must follow the procedures, emission factors, and methodological definitions established in the IPCC Guidelines, contributing to consistency between the Baseline and Project Scenarios.

Indirect emissions of $N_2O$ resulting from the application of nitrogen fertilizers must be calculated using Equation 7:

$$E_{\mathrm{N_2O}_{indir,e,t12}} = E_{\mathrm{N_2O}_{vol,t12}} + E_{\mathrm{N_2O}_{lix,t12}} \quad (7)$$

Where:

$E_{\mathrm{N_2O}_{indir,e,t12}}$= Indirect emissions of $N_2O$ from the project area in stratum "e" in year "$t_{12}$" [$tCO_2e$ (ha year)$^{-1}$];

$E_{\mathrm{N_2O}_{vol,t12}}$ = Indirect emissions of $N_2O$ produced by atmospheric deposition of volatilized N as a result of N application in the project area in year "$t_{12}$" [$tCO_2e$ (ha year)$^{-1}$];

$E_{\mathrm{N_2O}_{lix,t12}}$ = Indirect emissions of $N_2O$ produced by leaching and surface runoff of N as a result of N application in the project area in year "$t_{12}$" [$tCO_2e$ (ha year)$^{-1}$];

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

$t_{12}$ = Continuous period of 12 (twelve) months following the first application of nitrogen fertilizer.

Indirect emissions of $N_2O$ produced by atmospheric deposition of volatilized N must be calculated using Equation 8:

$$E_{\mathrm{N_2O}_{vol,t12}} = [(FN_{S,t12} * FracN_S) + (FN_{O,t12} * FracN_O)] * FE_{INV} * \frac{44}{28} * \mathrm{N_2O}_{GWP} \quad (8)$$

Where:

$E_{\mathrm{N_2O}_{vol,t12}}$ = Indirect emissions of $N_2O$ produced by atmospheric deposition of volatilized N as a result of N application in the project area in year "$t_{12}$" [$tCO_2e$ (ha year)$^{-1}$];

$FN_{S,t12}$ = Synthetic nitrogen fertilizer applied in year "$t_{12}$" [t N (ha year)$^{-1}$];

$FracN_S$ = Fraction of total synthetic N added to the soil that volatilizes as $NH_3$ and $NO_x$;

$FN_{O,t12}$ = Organic nitrogen fertilizer applied in year "$t_{12}$" [t N (ha year)$^{-1}$);

$FracN_O$ = Fraction of total organic N added to the soil that volatilizes as $NH_3$ and $NO_x$;

$FE_{INV}$ = Emission factor for indirect emissions of $N_2O$ from atmospheric deposition of N on soils and water surfaces [t $N_2O$ – N (t $NH_3$ – N + $NO_x$ – volatilized N)$^{-1}$];

$\frac{44}{28}$ = Ratio between the molecular weight of $N_2O$ and N [t $N_2O$ (t N)$^{-1}$];

$\mathrm{N_2O}_{GWP}$ = Global warming potential for $N_2O$ [$tCO_2e$ (t $N_2O$)$^{-1}$];

$t_{12}$ = Continuous period of 12 (twelve) months following the first application of nitrogen fertilizer.

Indirect emissions of $N_2O$ produced by atmospheric deposition of leached N must be calculated using Equation 9:

$$E_{\mathrm{N_2O}_{lix,t12}} = (FN_{S,t12} + FN_{O,t12}) * FracN_{lix} * FE_{INL} * \frac{44}{28} * \mathrm{N_2O}_{GWP} \quad (9)$$

Where:

$E_{\mathrm{N_2O}_{lix,t12}}$ = Indirect emissions of $N_2O$ produced by leaching and surface runoff of N as a result of N application in the project area in year "$t_{12}$" [$tCO_2e$ (ha year)$^{-1}$];

$FN_{S,t12}$ = Synthetic nitrogen fertilizer applied in year "$t_{12}$" [t N (ha year)$^{-1}$];

$FN_{O,t12}$ = Organic nitrogen fertilizer applied in year "$t_{12}$" [t N (ha year)$^{-1}$];

$FracN_{lix}$ = Fraction of N added to the soil (synthetic or organic) that is lost through leaching and surface runoff;

$FE_{INL}$ = Emission factor for indirect emissions of $N_2O$ from leaching and surface runoff of N (t $N_2O$ – N / t leached and runoff N)$^{-1}$;

$\frac{44}{28}$ = Ratio between the molecular weight of $N_2O$ and N [t $N_2O$ (t N)$^{-1}$];

$\mathrm{N_2O}_{GWP}$ = Global warming potential for $N_2O$ [$tCO_2e$ (t $N_2O$)$^{-1}$];

$t_{12}$ = Continuous period of 12 (twelve) months following the first application of nitrogen fertilizer.

O $FracN_S$ = Fraction of total synthetic N added to the soil that volatilizes as $NH_3$ and $NO_x$, o $FracN_O$ = Fraction of total organic N added to the soil that volatilizes as $NH_3$ and $NO_x$, o $FE_{INV}$ = Emission factor for indirect emissions of $N_2O$ from atmospheric deposition of N on soils and water surfaces, o $FracN_{lixiviado}$ = Fraction of N added to the soil (synthetic or organic) that is lost through leaching and surface runoff, and o $FE_{INL}$ = Emission factor for indirect emissions of $N_2O$ from leaching and surface runoff of N. The default values must be checked in Table 11.3 of the IPCC (2006, Volume 4, Chapter 11), and these values should be updated as new guidelines or refinements are published by the IPCC.

## 5.2 Liming

The application of carbonate-based acidity correctives, such as calcite limestone ($CaCO_3$) or dolomitic limestone ($CaMg(CO_3)_2$), results in the release bicarbonate ($HCO_3$), which, during the process of dissolution in the soil, is converted into carbon dioxide ($CO_2$) and water ($H_2O$). When liming constitutes an improved agricultural land management practice and the associated $CO_2$ emissions are considered significant, such emissions must be quantified in the Project Scenario, according to the applicable quantification approach.  Emissions generated by liming are quantified and reported in units of metric tons of carbon dioxide equivalent ($tCO_2e$).

The structure of variables used for quantifying GHG emissions from liming is presented in Figure 3.

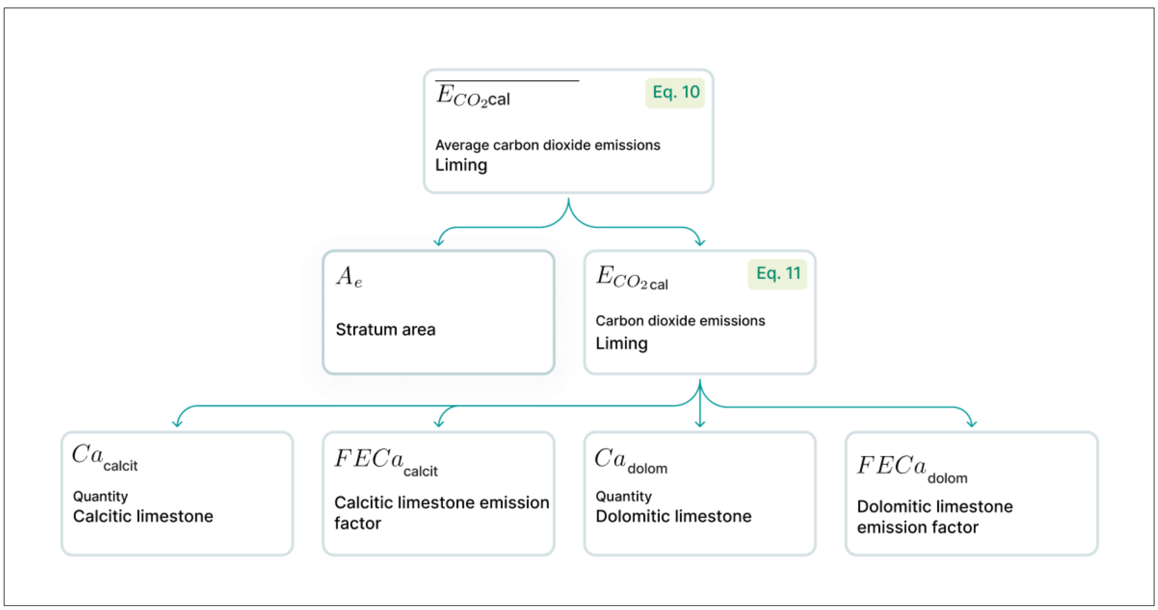


**Figure 3. Flowchart of equations for quantifying greenhouse gas emissions from the use of liming.**

For the calculation of average $CO_2$ emissions from liming, Equation 10 should be used:

$$\overline{E_{\mathrm{CO_2}\ cal,e,t12}} = \frac{E_{\mathrm{CO_2}\ cal,e,t12}}{A_e} \quad (10)$$

Where:

$\overline{E_{\mathrm{CO_2}\ cal,e,t12}}$ = Average $CO_2e$ emissions from the area due to liming in stratum “e” in year “$t_{12}$” ($t\ CO_2\ ha^{-1}$);

$E_{\mathrm{CO_2}\ cal,e,t12}$ = $CO_2e$ emissions from liming in stratum “e” in year “$t_{12}$” ($t\ CO_2e$);

$A_e$ = Stratum area (ha);

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

$t_{12}$ = Continuous period of 12 (twelve) months following the first application of nitrogen fertilizer.

For the calculation of carbon dioxide emissions from liming, Equation 11 should be used:

$$E_{CO_2\ cal,e,t12} = ((Ca_{calcit,e,t12} * FECa_{calcit}) + (Ca_{dolom,e,t12} * FECa_{dolom})) * \frac{44}{12} \qquad (11)$$

Where:

$E_{CO_2\ cal,e,t12}$ = $CO_2e$ emissions from liming in stratum “e” in year “$t_{12}$” (t $CO_2e$);

$Ca_{calcit,e,t12}$ = Amount of calcitic limestone ($CaCO_3$) applied in stratum “e” in year “$t_{12}$” (ton);

$FECa_{calcit}$ = Emission factor for calcitic limestone [t C (t limestone)$^{-1}$];

$Ca_{dolom,u,t12}$ = Amount of dolomitic limestone ($CaMg(CO_3)_2$) applied in stratum “e” in year “$t_{12}$” (ton);

$FECa_{dolom}$ = Emission factor for dolomitic limestone [t C (t dolomite)$^{-1}$];

$\frac{44}{12}$ = Ratio between the molecular weight of $CO_2$ and carbon to convert $CO_2$ – C emissions into $CO_2$ emissions;

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

$t_{12}$ = Continuous period of 12 (twelve) months following the first application of nitrogen fertilizer.

O $FECa_{calcit}$ = Emission factor for calcitic limestone and $FECa_{dolom}$ = emission factor for dolomitic limestone, the default values must be checked in section 11.3 of the IPCC (2006, Volume 4, Chapter 11), and these values should be updated as new guidelines or refinements are published by the IPCC.

# 6. Machinery Fossil Fuel

## 6.1 Identification of Emission Sources

The GHG emission sources associated with the use of fossil fuels from machinery are identified in the Baseline and Project Scenarios, exclusively considering the direct emissions resulting from the combustion of fossil fuels in mobile equipment. These include, among others, tractors, harvesters, trucks, generators, and similar equipment used in agricultural and internal logistics operations, such as soil preparation, planting, management, harvesting, and internal transport.

In the Baseline Scenario, only emissions that would occur in the absence of the project are considered, provided they are associated with plausible, recurrent uses and duly demonstrated based on the area's usage history or prevailing regional practices. In the Project Scenario, the emission sources corresponding to the activities implemented are identified, contributing to methodological consistency, traceability, and relevance of the sources accounted for.

The emission estimate can be made based on direct fuel consumption or, alternatively, from equipment activity data (such as distance traveled or hours of operation), provided that appropriate conversion factors are applied for estimating fuel consumption. The Project Designer must present the data used in monitoring to the VVB, as well as the conversion factors adopted and the assumptions made when calculating fuel consumption. In accordance with IPCC guidelines, emissions of $CO_2$, $CH_4$ and $N_2O$ should preferably be estimated based on fuel consumption. In the absence of consumption data, estimation based on activity parameters is allowed provided that consistent and methodologically justifiable emission factors are adopted.

## 6.2 Total Calculation of Emissions by Fuel Consumption

The structure of variables used for quantifying GHG emissions from fossil fuel consumption is presented in Figure 4. The emissions generated by the combustion of fossil fuels are quantified by GHG and reported in units of metric tons of carbon dioxide equivalent ($tCO_2e$).

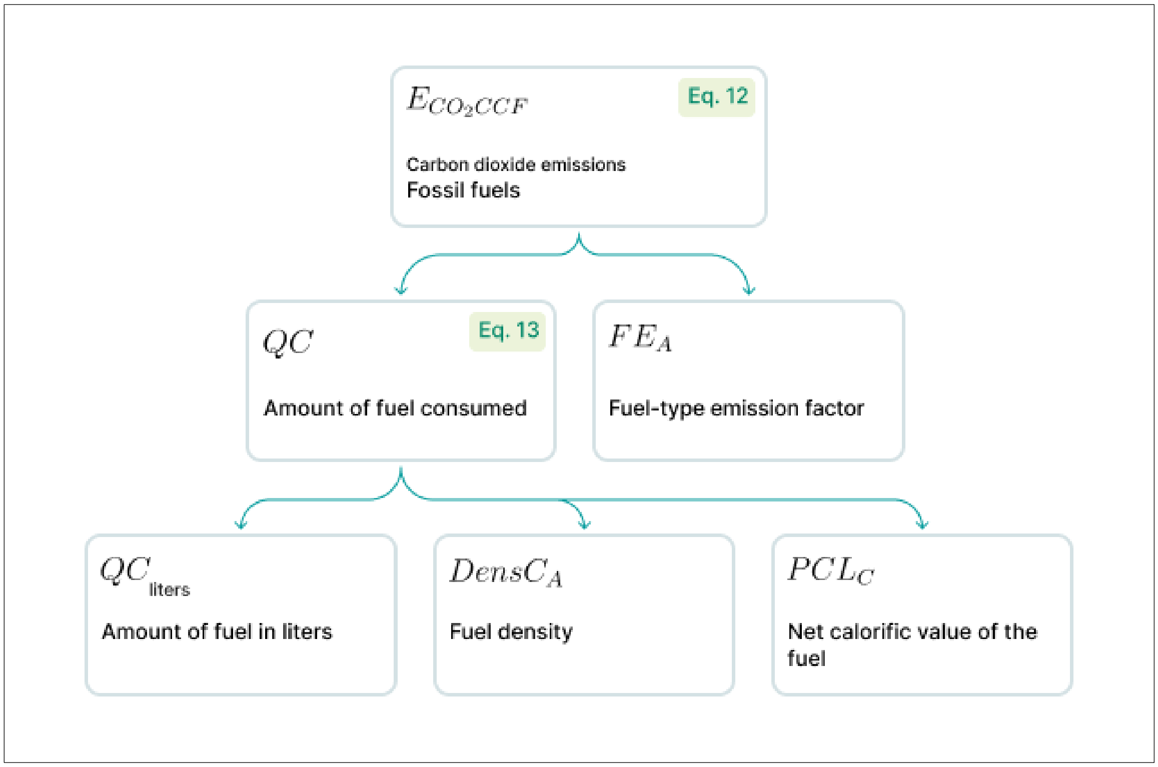


**Figure 4. Flowchart of the equations for quantifying greenhouse gas emissions from fossil fuel consumption.**

The emissions associated with fossil fuel combustion activities during the monitoring period must be quantified according to Equation 12:

$$E_{\mathrm{CO_2CCf,e,t}} = \sum_{a=1}^{A}(QC_{A,cons,e,t} \; * \; FE_A) \tag{12}$$

Where:

$E_{\mathrm{CO_2CCf,e,t}}$ = Net $CO_2e$ emissions from the burning of fossil fuels in stratum “e” in year “t” (t $CO_2e$);

$QC_{A,cons,e,t}$ = Amount of fuel type “A” consumed in stratum “e” in year “t” (TJ);

$FE_A$ = Emission factor for fuel type “A” [t $CO_2e$ $(TJ)^{-1}$];

a = 1, 2, 3 A types of fuel (e.g.: gasoline, diesel, etc.);

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

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

The annual amount of fuel consumed, by type, in year t must be estimated according to Equation 13:

$$QC_{A,cons,e,t} = (QC_{litros,A,cons,e,t} * DensC_A * PCL_{C,A}) \div 10^6 \quad (13)$$

Where:

$QC_{A,cons,e,t}$ = Amount of fuel type "A" consumed in stratum "e" in year "t" (TJ);

$QC_{litros,A,cons,e,t}$ = Amount of fuel in liters of type "A" consumed in stratum "e" in year "t" (liters);

$DensC_A$ = Density of fuel type "A" [kg (liter)$^{-1}$];

$PCL_{C,A}$ = Net calorific value of fuel type "A" [TJ (Gg)$^{-1}$];

$10^6$ = Used for unit conversion, transforming the energy value from megajoules (MJ) to terajoules (TJ), as required for emissions accounting;

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

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

The $FE_A$ = Emission factor for fuel type A, standard values must be obtained from the IPCC guidelines (2006, Volume 2, Chapter 3), and should be updated as new guidelines, refinements, or revisions are officially published by the IPCC. The $DensC_A$ = Density of fuel type A and the $PCL_{C,A}$ = Net calorific value of fuel type A, standard values must be checked in the annual BEN – National Energy Balance report, and these values should be updated as new guidelines or refinements are published by BEN (EPE, 2025).

In the Project Scenario, fossil fuel consumption must be quantified separately for each type of fuel used and for each monitoring period. When applicable, quantification must use measurable and traceable data, including but not limited to: operational records, field logs, invoices, fueling controls, and other equivalent control systems. For the calculation of GHG emissions from fuel consumption, the Project Designer must follow a hierarchical data approach, in the following order:

a. direct measurements, when controlled by the Project Designer;
b. fueling records (for example, invoices or consumption controls);
c. operational logs (for example: hours of operation or distance traveled);
d. technical parameters (for example: manufacturer-specific consumption or standard factors).

## 6.3 Estimation of Fuel Consumption in the Absence of Direct Measurements

In the absence of direct measurement data, fossil fuel consumption associated with machinery use can be estimated through indirect approaches based on activity parameters, provided they are technically justified, conservative, and consistent with applicable IPCC Guidelines (as per the data hierarchy presented in section 6.2).

a. Estimation based on the equipment's known operational parameters:

Fuel consumption can be estimated from technical and operational information of the machinery, such as hours of operation, rated power, average load factor, and specific fuel consumption. The parameters adopted must be compatible with the type of equipment and the nature of the operations performed, preferably obtained from manufacturer manuals, recognized technical literature, or widely accepted reference values.

b. Estimation based on transport activity:

For vehicles used in internal transport operations, fuel consumption can be estimated based on vehicle activity, demonstrated by distance traveled or volume of operation, in combination with average consumption factors appropriate to the type of vehicle and operational conditions.

The Project Designer must clearly and transparently document the approach adopted, including the assumptions, parameters, data sources, and technical justifications used in the fuel consumption estimate. This documentation must be made available for validation and verification by the VVB, contributing to traceability, methodological consistency, and auditability of the results.

# 7. Sustainable Forest Management

## 7.1 Description of Activities for Reduction or Loss of Carbon Stocks

Sustainable forest management activities reduce carbon stocks due to the operations required for forest harvesting. These emissions are related, where applicable, to the following activities:

a. Opening of logging clearings, including damage to remaining vegetation, resulting in a temporary reduction of aboveground biomass carbon stocks;

b. Implementation and use of forest harvesting infrastructure, such as roads, skid trails, extraction trails, and storage yards, associated with the temporary conversion of forest areas and carbon loss.

According to Law No. 12.651/2012 of the Brazilian Forest Code, sustainable management is defined in Art. 3, item VII, as:

> "...*management of natural vegetation to obtain economic, social, and environmental benefits, respecting the support mechanisms of the ecosystem under management and considering, cumulatively or alternatively, the use of multiple timber or non-timber species, multiple products and by-products of the flora, as well as the use of other goods and services*."

## 7.2 Activities Associated with the Reduction of Carbon Stocks

### 7.2.1 Reduction of carbon stocks resulting from the opening of logging clearings

In the Project Scenario, reductions in carbon stocks result directly from the mortality of additional trees affected by collateral damage during the felling of commercial trees. The net emission in the project scenario corresponds to logging damage, calculated by applying the damage factor to the extracted volume and to the carbon stocks of woody biomass above and below ground, with subsequent aggregation for the strata.

The structure of variables used for quantifying the reduction of carbon stocks resulting from the opening of logging clearings in sustainable forest management is presented in Figure 5. Such reductions in carbon stocks are accounted for as emissions from the Project Activity, being quantified and reported in units of metric tons of carbon dioxide equivalent ($tCO_2e$).

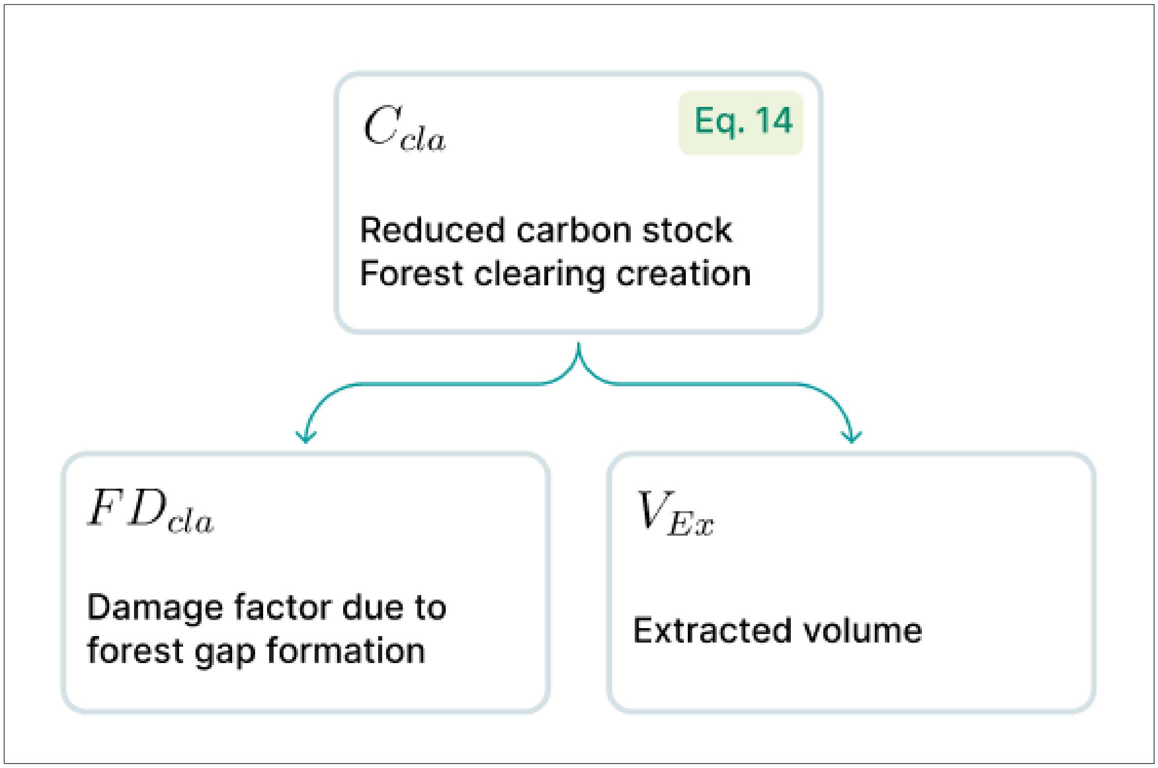


**Figure 5. Flowchart of the equations for quantifying the reduction of carbon stocks resulting from the opening of logging clearings.**

For the calculation of carbon stocks reduced by the opening of clearings, Equation 14 should be used.

$$C_{cla,e,t} = \sum_{z=1}^{Z} (FD_{cla} * V_{Ex\_z,e,t} * \frac{44}{12}) \tag{14}$$

Where:

$C_{cla,e,t}$ = Carbon stock reduced by the opening of logging clearings in stratum “e” in year “t” (t $CO_2e$);

$FD_{cla}$ = Damage factor caused by the opening of clearings (t C $m^{-3}$);

$V_{Ex\_z,e,t}$ = Volume extracted from logging stratum “z”, in stratum “e” in year “t” ($m^3$);

$\frac{44}{12}$ = Ratio between the molecular weight of $CO_2$ and C;

z = Forest harvesting strata;

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

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

At the first hierarchical level of prioritizing methodological choice, the Project Designer must calculate the damage factor associated with the opening of clearings $FD_{cla}$ based on primary data measured in their own Project Area, considering the activities carried out. The calculation must reflect, at a minimum, the amount of biomass affected, the degree of soil disturbance, and the harvesting intensity.

Primary data must be prioritized, and the methodology used for the collection, processing, and analysis of this information must be properly documented and presented to the VVB during Validation and/or Verification Audits.

The Project Designer may use primary data from other projects under their responsibility, provided that they are technically compatible and representative of the conditions of the Project Area. The use of this data must be properly justified, documented, and made available for audit and traceability purposes.

At the second hierarchical level of prioritizing methodological choice, the Project Designer may use damage factor data associated with the opening of harvesting clearings from scientific literature, provided that it complies with the stages of the certification process in which the use of secondary data is allowed, as established in each methodology. The Project Designer must follow the following hierarchy of reference sources:

1. Damage factors associated with the opening of harvesting clearings from scientific literature, provided that such values are technically compatible with the conditions of the Project Area. This use must be restricted to studies that demonstrate similar ranges of harvesting intensity and biomass quantity, ensuring the representativeness and adherence of the data to the project context. Furthermore, the choice of references must be properly justified and documented, ensuring transparency and methodological consistency.

2. 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%.

The Project Designer must prioritize data that are compatible at the phytophysiognomy level (or actual formation, according to the IBGE definition) with the Project Area. Furthermore, the data must refer to the same biome in which the project is located.

The indexed platforms SciELO, Web of Science and Scopus were chosen as references for the selection of scientific articles, as they carry out formal evaluation processes conducted by scientific and/or editorial committees, based on technical and editorial criteria, including but not limited to peer review, quality of journal articles, and contribution to the relevant field.

If the Project Designer uses scientific references not indexed on the SciELO, Web of Science or Scopus platforms, they must present a technical justification to the Validation and Verification Body (VVB) regarding the choice and adequacy of the adopted data. The justification must demonstrate the reliability, relevance, and applicability of the references used to the project context.

### 7.2.2 Reduction of carbon stocks resulting from the implementation and operation of forest harvesting infrastructure

The reduction of carbon stocks in selective forest harvesting operations is associated with the opening and use of extraction trails, storage yards, and forest roads. The net emission in the Project Scenario corresponds to the damages associated with harvesting activities and the implementation of infrastructure, being calculated by applying the damage factors to the affected volumes and the respective carbon stocks of the reservoirs.

The methodological structure for quantifying the reduction of carbon stocks resulting from the implementation and operation of forest harvesting infrastructure is presented in Figure 6, sequentially organizing the main variables involved in the calculation, including the carbon stock reduced as a function of the damage factor associated with the infrastructure, the volume extracted from the harvesting stratum, and the total carbon stock in all reservoirs, as well as the breakdown of the damage factor into the contributions of extraction trails, storage yards, and road openings.

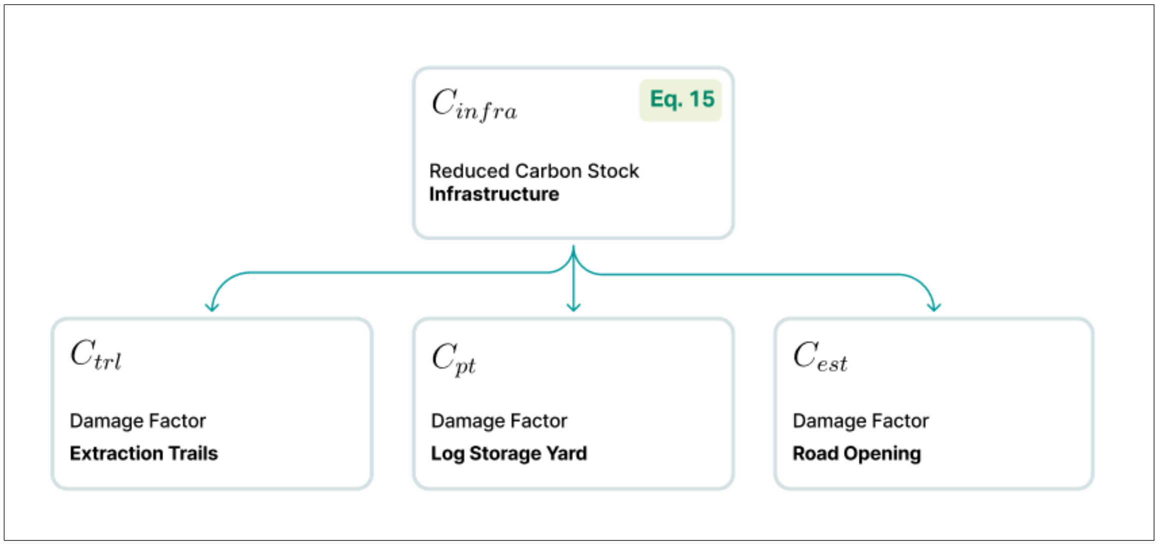


**Figure 6. Flowchart of the equations for quantifying the reduction of carbon stocks resulting from the implementation and operation of forest harvesting infrastructure.**

The results are subsequently aggregated for the strata and estimated according to Equation 15.

$$C_{infra,e,t} = \sum_{z=1}^{Z} C_{trl} + C_{pt} + C_{est} \tag{15}$$

$C_{infra,e,t}$ = Carbon stock reduced by the construction of harvesting infrastructure in stratum "e" in year "t" (t $CO_2e$);

$C_{trl}$ = Carbon stock reduced by the construction of skid trails in stratum "e" in year "t" (t $CO_2e$);

$C_{pt}$ = Carbon stock reduced by the construction of storage yards in stratum "e" in year "t" (t $CO_2e$);

$C_{est}$ = Carbon stock reduced by the construction of roads in stratum "e" in year "t" (t $CO_2e$);

z = Forest harvesting strata (dimensionless);

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

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

At the first hierarchical level of prioritizing methodological choice, the Project Designer must calculate the damage factor associated with the infrastructure $C_{trl}$, $C_{pt}$ and $C_{est}$ based on primary data measured in their own Project Area, considering the activities carried out. The calculation must reflect, at a minimum, the amount of infrastructure installed, the dimensions of the openings, the amount of biomass affected, the degree of soil disturbance, and the intensity of harvesting.

Primary data must be prioritized, and the methodology used for the collection, processing, and analysis of this information must be properly documented and presented to the VVB during Validation and/or Verification Audits.

The Project Designer may use primary data from other projects under their responsibility, provided that they are technically compatible and representative of the conditions of the application area. The use of this data must be properly justified, documented, and made available for audit and traceability purposes.

At the second hierarchical level of prioritizing methodological choice, the Project Designer may use damage factor data associated with the opening of harvesting clearings from scientific literature, provided that it complies with the stages of the certification process in which the use of secondary data is allowed, as established in each methodology. The Project Designer must follow the following hierarchy of reference sources:

1. Damage factors associated with the opening of harvesting clearings from scientific literature, provided that such values are technically compatible with the conditions of the Project Area. This use must be restricted to studies that present similar ranges of harvesting intensity and biomass quantity, ensuring the representativeness and adherence of the data to the project context. Furthermore, the choice of references must be properly justified and documented, ensuring transparency and methodological consistency.

2. 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%.

The Project Designer must prioritize data that are compatible at the phytophysiognomy level (or actual formation, according to the IBGE definition) with the Project Area. Furthermore, the data must refer to the same biome in which the project is located.

The indexed platforms SciELO, Web of Science and Scopus were chosen as references for the selection of scientific articles, as they carry out formal evaluation processes conducted by scientific and/or editorial committees, based on technical and editorial criteria, including but not limited to peer review, quality of journal articles, and contribution to the relevant field.

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# 8. References


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