Gold Standard for the Global Goals

Climate Security & Sustainable Development

ACTIVITY MODULE METHODOLOGY

SOIL ORGANIC CARBON ACTIVITY MODULE FOR COVER CROPS

SDG 13

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Soil Organic Carbon Framework Methodology, Version 1.0

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1| Summary

This Soil Organic Carbon Activity Module (hereafter referred to as "this Activity Module") focuses on cover crops planted to cover the bare soil during fallow periods to increase soil organic carbon (SOC). It is applicable globally.

In a typical baseline situation, crop fields are left bare (i.e., without plant growth) from the time of harvest until the next crop is planted (fallow period). The project introduces cover crops to be planted during the fallow period to cover the soil and keep roots in the soil, which improves soil condition and increases SOC.

This Activity Module addresses different categories of cover crops (legumes, non-legumes, grasses, and brassicas) and options for cover crop application depending on and aligning with the associated practices (reduced till, no-till) that are implemented. Cover cropping can comprise a single species or a mixture of species and can use annual, biennial, or perennial vegetation. At the end of the fallow period, cover crops are usually terminated to prevent competition with the primary crop and to allow the timely planting of the next crop. In no-till approaches, cover crops are left on the soil surface to support weed control (Osipitan et al. 2018, Osipitan et al. 2019) and nitrogen inputs before a primary crop is planted (Abdalla et al. 2019). Grazing may also be used to terminate cover crops.

In line with the Soil Organic Carbon Framework Methodology, this Activity Module provides three approaches for quantification of SOC increase. This accommodates that not all relevant measurements and parameters may be available to projects. Approach 1 requires on-site measurements to directly document pre-project and project SOC stock levels; Approach 2 uses datasets, parameters, and/or models from peer-reviewed publications to quantify baseline and project SOC stock levels; and Approach 3 applies default factors to quantify SOC changes relating to the general methodology described in the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (hereafter referred to as "IPCC 2019"), using a Tier 2–level approach whenever possible. For Approaches 2 and 3, project developers shall document that the coefficients applied are conservative and applicable to the project site and management practice.

2| Definitions and References

2.1 | Definitions

2.1.1 | Terms and definitions are listed in the Soil Organic Carbon Framework Methodology, Section 2.1. In addition, the following module-specific definitions apply:

Term	Definition
Farm	A farm is an area of land that is devoted primarily to agricultural processes with the primary objective of rearing livestock or producing food and other crops. Under this Activity Module, 'farm' encompasses all such lands legally registered as part of the farm's holdings as well as associated leased lands with a valid contract.
Cover crop	A cover crop is a close-growing, dense canopy crop that provides soil protection, seedling protection, and soil improvement between periods of normal crop production (Soil Science Society of America, 2008). A cover crop is not harvested, and biomass is not removed from a field (this is particularly relevant to SOC).
Full tillage (full-till)	Full tillage refers to field practices leading to substantial soil disturbance with full inversion and/or frequent, within-year tillage operations, while leaving <30% of the surface covered by residues at the time of planting (IPCC 2019, Volume 4, Chapter 5, Section 5.2.3.3).
Reduced tillage (reduced-till)	Reduced tillage refers to field practices with primary and/or secondary tillage but with reduced soil disturbance that is usually shallow and without full soil inversion; this normally leaves surface with >30% coverage by residues at planting (IPCC 2019, Volume 4, Chapter 4, Section 5.2.3.3).
Zero tillage (no-till)	Zero tillage is an agricultural technique for growing crops or pasture without mechanically disturbing the soil through tillage (including disturbance from non-turning tillage such as rippers and disc harrows). Crop is sown directly into soil that has not been tilled since the harvest of the previous crop. Zero tillage has more than 30% cover of the soil surface with residues.

2.2 | References

2.2.1 | In addition to the methodologies, methodological tools, guidelines, and key sources listed in the Soil Organic Carbon Framework Methodology, this Activity Module refers to the following key publications:

2.2.2 |

- IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry and Other Land Use (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html).
- IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry and Other Land Use (https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html).
- Osipitan, O. A., Dille, J. A., Assefa, Y., Knezevic, S. Z., 2018. Cover crop for early season weed suppression in crops: systematic review and meta-analysis. *Agronomy Journal* 110: 2211-2221. https://doi.org/10.2134/agronj2017.12.0752
- Osipitan, O. A., Dille, J. A., Assefa, Y., Radicetti, E., Ayeni, A., Knezevic, S. Z., 2019. Impact of cover crop management on level of weed suppression: a meta-analysis. *Crop Science* 59: 833-842. https://doi.org/10.2135/cropsci2018.09.0589
- Soil Science Society of America, 2008. Glossary of Soil Science Terms. Soil Science Society of America, Madison, Wisconsin. 88 pp.

3| Applicability

3.1.1 | A project applying this Activity Module shall comply with the applicability conditions specified below and with those in the Soil Organic Carbon Framework Methodology. In addition, the project shall comply with applicable Land Use & Forests Activity Requirements (hereafter referred to as "LUF Activity Requirements" or Agriculture Activity Requirements when published and in force) and the Gold Standard for the Global Goals Principles & Requirements (hereafter referred to as "Principles & Requirements").

3.1.2 | Applicability conditions:

- Projects are eligible in all countries.
- Generally, entire farms or selected fields/areas of a farm are eligible (see Section 5.1: Spatial Boundary).

- The Activity Module shall not be applicable to farms which have been using cover crops for more than one season within five years prior to project start, even if such application was on fields not included in the project.
- In line with the Soil Organic Carbon Framework Methodology, this Activity Module accounts for only those benefits in the SOC pool. No other pools or emission reductions (e.g., in nitrous oxide [N_2O] due to reduced fertiliser need) can be accounted for as benefits.
- Cover cropping can comprise a single species or a mixture of species and can use annual, biennial, or perennial vegetation.

3.1.3 | Other than cover crops, organic carbon inputs to the field shall not be changed as part of the project by more than 5% from baseline period average. If this Activity Module is stacked with an additional Gold Standard methodology or activity module which uses the same quantification approach in the project (measurement or compatible SOC model allowing distinction of impacts between cover crops and organic inputs from other practice changes) and considers respective leakage effects, this applicability condition may be omitted.

- If the project includes change of tillage practices, the same quantification approach (measurements, models, or defaults) shall be used for both activities and shall be fully aligned to ensure that overall benefits are quantified correctly and not double-counted. Changes in tillage practices shall be documented and shall follow quantification approaches according to a respective Gold Standard–approved methodology or activity module.

3.1.4 | Application of herbicides to terminate cover crops shall be minimised, and negative environmental impacts shall be prevented in accordance with Gold Standard Safeguarding Principle 9.6 (Pesticides & Fertilisers). Use of herbicides related to the project, specifically for crop termination and weed control, shall not be increased by more than 5% from baseline period average.

4| Additionality

4.1.1 | All Gold Standard projects shall demonstrate that they would not have been implemented without the benefits of carbon revenue. Specific rules and guidelines on how to assess additionality are in the Additionality section of the LUF Activity Requirements and the Additionality Requirements for Agriculture Projects Template.

5| Project Boundaries

5.1 | Spatial Boundary

5.1.1 | For spatial boundaries, the rules and requirements defined in Soil Organic Carbon Framework Methodology apply.

5.1.2 | Spatial boundary description specific to this Activity Module:

- Generally, entire farms or selected fields/areas of a farm are eligible. If the project is implemented only on selected fields, all applicability conditions and requirements in the Soil Organic Carbon Framework Methodology (including maintaining yield) and from this Activity Module shall be applied to these specific fields. These fields shall remain in the project during the entire crediting period (i.e., no change of participating fields within a farm during the crediting period is allowed).
- This Activity Module requires greenhouse gas (GHG) sources, sinks, and reservoirs (SSR) as identified in Figure 5-01 to be considered, with a focus on their impact on SOC and increase of emissions from the project. The boundary thus includes all impacted field activities (machine use, tillage, application of fertiliser and pesticides), including main crop practices. As SOC increase from cover crops is driven primarily through inputs of biomass (root and residue) as well as rhizodeposits, growth and residue management for cover crops is essential to assess SOC impact. For the same reason, other organic inputs (e.g., manure, compost) shall be monitored. As the project newly introduces cover crops to the field, emissions from the production and transport of seeds shall be considered. As no changes are expected to be made to farm infrastructure or handling of main crops, these activities are not included in the project boundary for quantification.

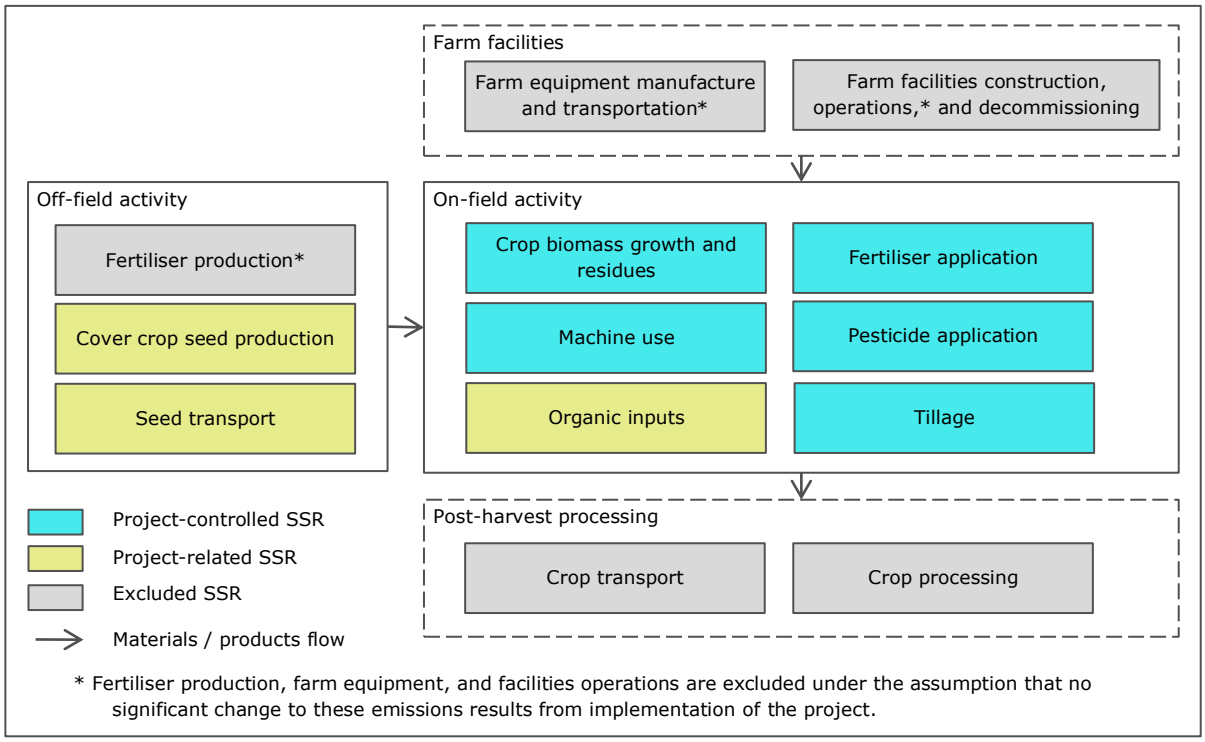

Figure 5-01: Spatial Project Boundary

5.2 | Temporal Boundary

5.2.1 | This Activity Module requires a crediting period of 10 years to account for the slow SOC buildup and to ensure long-term SOC impacts. The crediting period can be renewed once.

5.3 | Carbon Pools

5.3.1 | Carbon pool description

- In line with the Soil Organic Carbon Framework Methodology, this Activity Module accounts for only those benefits in the SOC pool. Additional pools (e.g., biomass and litter) may be used for calculation of SOC change, but no GHG sequestration in pools other than SOC shall be accounted for as benefits.
- No emission reduction from other GHG sources (e.g., fossil fuel use or fertiliser application) shall be reported for benefits under this Activity Module.

5.4 | Greenhouse Gases

5.4.1 | Following the Soil Organic Carbon Framework Methodology, all GHG sinks and sources affected by its activities shall be monitored.

5.4.2 | For this Activity Module, this specifically includes any significant increases in carbon dioxide (CO_2), methane (CH_4), and N_2O emissions from the project.

6| Emission Reduction Quantification Approach

Calculations for overall benefits follow the equations in the Emissions Reduction Quantification Approaches section of the Soil Organic Carbon Framework Methodology. The following sections describe the approaches and calculations that are specific to this Activity Module.

6.1 | Approaches for Baseline and Project Scenario Quantification

6.1.1 | This Activity Module allows application of all three quantification approaches as described in the Soil Organic Carbon Framework Methodology. Project proponents shall select the most specific approach possible with the data available, giving preference to local data sources and models as outlined in the decision tree in Figure 2 of the Soil Organic Carbon Framework Methodology.

6.2 | Approach 1 (On-Site Measurements of Soil Organic Carbon)

6.2.1 | Additional requirements:

- SOC measurements shall be taken at a suitable time of year, e.g., at the beginning of the season for main crops, with repeated measurements performed at the same time of the year to avoid bias due to short-term variation in soil carbon pools (e.g., after harvest of main crops and tilling of crop residue into the soil). The project documentation shall specify the timing of soil sampling, i.e., the season and crop rotation phase, as applicable, to be implemented by all sampled farms in the project or program.
- To avoid overestimation of SOC stocks, measurements shall always be performed *before* any significant carbon inputs such as organic or partially organic fertilisers, including compost and manure, as well as other carbon sources, e.g., in lime or other soil inputs and soil disturbance events (tillage).
- Bulk density shall be considered in all quantification approaches. Quantification shall be done on an "equivalent mass basis" to properly quantify carbon impacts, i.e., if increased bulk density is measured in the project scenario, respective layer depth shall be reduced proportionally when calculating SOC change.

6.2.2 | Special care shall be taken to ensure that litter on the soil surface (crop residue) is not included in the SOC quantification.

6.3 | Approach 2 (Application of Models, Research Data)

6.3.1 | Additional requirements:

- Project developers shall provide evidence that calculation approaches, datasets, parameters, and models from peer-reviewed publications to estimate baseline and project SOC stocks in the project are conservative and applicable to the project site conditions and management practices.[1] In accordance with the LUF Activity Requirements, "conservativeness" shall mean that from a range of available data, the value resulting in lower GHG benefits shall be applied.
- Models and datasets applied shall be calibrated locally, i.e., using project-specific data. Global models without such local parametrisation and validation shall not be applied. Application of global defaults for soil respiration, e.g., "Q_{10}" values to quantify temperature effects on respiration, is not allowed.
- Project documentation shall include evidence that the sources used are applicable to main crops and levels of yield (production intensity), management practices (e.g., tillage[2]), and cover crop species and practices (e.g., duration of cover crop growth) used in the project area for baseline and project scenarios. Evidence shall also be provided that datasets and models have sufficient temporal resolution (i.e., multiple data points per year) to account for impacts of seasonal variations in practices and other factors such as changing weather conditions. If the model used does not allow seasonal crop and practice variations, data shall be aggregated to a representative annual value with and without cover crops.
- Parameters for process-based models shall be calibrated and verified following best practice, using at least five years of data for calibration and three years of independent data for verification. Both calibration and verification datasets shall match project conditions as outlined above. Any

[1] Refer to stratification criteria (Section 7.1.4) for factors determining applicability to project conditions. All factors listed for stratification shall be assessed to confirm applicability.
[2] Changes in tillage due to cover crops shall be represented in the model parameters at the level required by the specific model applied.

gaps in datasets and procedures and how they were addressed in the model calibration and verification shall be reported at validation.

- SOC measurements for a representative sample in each stratum of the project area shall be made at project start and at least once every five years, applying proven methodology (see Section 6.2 above) and using statistically assessed model results or research data for quantification. If significant differences from modelled results or research data are found, models shall be refined.

6.4 | Approach 3 (Default Factors and IPCC Models)

6.4.1 | Additional requirements: For Approach 3, this Activity Module provides two alternative calculations in addition to the IPCC Tier 1/2 approach as listed in the Soil Organic Carbon Framework Methodology:

- Approach 3.1 follows the method described in the Soil Organic Carbon Framework Methodology but requires Tier 2 data (instead of global defaults) to allow calculation for cover crops.
- Approach 3.2 applies the "Steady State Method" that was also introduced in IPCC 2019. This approach is somewhat more complex in calculation but uses a different set of data that is more readily available for cropping systems and is also applicable to cover crops.

6.4.2 | **Approach 3.1** applies default equations to estimate SOC changes as described for Approach 3 in the Soil Organic Carbon Framework Methodology, based on a Tier 2 approach according to IPCC 2019. Cover crop residue shall be considered as "organic inputs" only. However, as no specific stock change factors for cover crops are available in the IPCC guidelines, national or regional Tier 2 parameters for organic input stock change factors specific to cover crops must be used, in line with the Soil Organic Carbon Framework Methodology. This Activity Module thus requires that national or regional Tier 2 SOC reference values (SOC_{REF}) and stock change factors shall be applied in Equations 4 and 6 of the Soil Organic Carbon Framework Methodology. If tillage practices are changed due to the introduction of cover crops, stock change factors for tillage practices (see Section 2.1.1 for definitions) shall also be applied in accordance with the Tier 2 data source.

6.4.3 | **Approach 3.2** applies the IPCC Tier 2 "Steady State Approach" according to IPCC 2019, Volume 4, Chapter 5 (see Table 6-01 for references). When applying the Steady State Method at the project level, the following interpretation and additional guidance shall be applied to the IPCC 2019 descriptions and procedures:

- The IPCC 2019 term "grid cell or region" shall be interpreted as field strata or individual fields, as appropriate to achieve conservative results at the field level within Gold Standard uncertainty requirements.
- Quantification shall consider all inputs to the fields for baseline and project scenarios at the field or field stratum level, including inputs from all crops separately (harvested crops for baseline; harvested crops plus cover crops for project scenario), as well as potential other organic inputs such as green manure, compost, or animal manure.
- Change in tillage practices (see Section 2.1.1 for definitions) due to cover crop management shall be considered per the guidance provided in IPCC 2019 and in accordance with the Tier 2 data source.
- Project-specific data and parameters shall be applied if available. Evidence for applicability of such data shall be provided with the project documentation.
- If no project-specific data is available, Tier 2 parameters listed in IPCC 2019 (see Table 6-01 below) may be applied, considering parameter uncertainties as listed. It is recommended to perform a sensitivity analysis with minimum and maximum input parameters to ensure conservative benefits estimations in case of high uncertainties. Note: Crop volumes, soil, and weather data used in the quantification shall always be based on local information.
- All input parameters used in this approach shall be monitored and reported, including source and rationale for selection (see Section 12).
- If the project includes tillage changes, Approach 3.2 shall be applied only if no separate calculation of tillage impacts on SOC is performed (e.g., not applying any separate SOC modules under the Soil Organic Carbon Framework Methodology or other tillage-focused methodology to account for SOC benefits from tillage change).
- For reference, the calculation spreadsheet and example data provided in IPCC 2019 may be consulted (see reference in Table 6-01). Application shall require the use of appropriate datasets as described above.

Table 6-01: Key References to IPCC 2019 Steady State Method

TOPIC	REFERENCE IPCC 2019, VOL. 4, CHAPTER 5
Description of Steady State Method	Pages 5.15 to 5.18
Step-by-step procedure	Pages 5.23 to 5.26
Equations for Steady State Method	Pages 5.18 to 5.23
Default value table for model parameters	Table 5.5A, page 5.31
Default value table for nitrogen and lignin contents in crops	Table 5.5B, page 5.32
Default value table for carbon to nitrogen ratios and lignin contents in livestock manure	Table 5.5C, page 5.33
Tier 2 Steady State Method spreadsheet (MS Excel)	Separate tool[3]

7| Baseline Scenario

7.1 | Baseline Calculations

7.1.1 | Quantification for SOC in the baseline ($SOC_{BL,y}$) shall follow the rules, approaches, calculations, and parameters in the Baseline Scenario section of the Soil Organic Carbon Framework Methodology.

7.1.2 | Baseline data is required for five years per the Soil Organic Carbon Framework Methodology. If five-year baseline data is not fully available for a field within a stratum (e.g., it was leased less than five years prior to project start), evidence shall be provided that average baseline conditions for the stratum apply to the field lacking data, referencing the stratification criteria described below.

7.1.3 | Baseline period may be extended to cover full rotation periods; avoid including fragments of rotations in the baseline quantification, e.g., in a three-year crop rotation system, a six-year baseline period will deliver more consistent results, including all relevant practices, inputs, and crop yields for two full rotations.

[3] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/Vol4_Ch5_Tier2_Steady_State_Method-Spreadsheet.xlsx

7.1.4 | To determine the baseline of the eligible project area, the land shall be stratified into modelling units (MUs) according to criteria in Section 6 of the Soil Organic Carbon Framework Methodology. In addition, the following criteria shall be considered in stratification:

- Mineral soil type[4]
- Tillage practices
- Specific crops (and crop rotations) and production period
- Productivity (e.g., net primary productivity or crop yield)
- Fallow (bare) period

For each stratum (MU), SOC measurements shall be performed (Approach 1) and/or model parameters shall be identified and verified (Approach 2 or 3).

7.1.5 | If a model is used to quantify baseline SOC (Approach 2), full transparency shall be provided on input data and parametrisation. Application of "black box" models is not allowed.

8| Project Scenario

8.1 | Project Calculations

8.1.1 | Quantification for SOC in the project scenario ($SOC_{t,y}$) shall follow the rules, approaches, calculations, and parameters in the Project Scenario section of the Soil Organic Carbon Framework Methodology.

8.1.2 | This Activity Module addresses different categories of cover crops (legumes, non-legumes, grasses, and brassicas) and options for cover crop application depending on and aligning with the associated practices (reduced till, no-till) that are implemented. Cover cropping can comprise a single species or a mixture of species and can use annual, biennial, or perennial vegetation. Quantifications for all approaches shall consider specific cover crops and practices (including cover crop termination and residue cover) applied. When measuring (Approach 1), respective criteria shall be considered in the project area stratification for sampling. For model application (Approach 2 or 3), calculation and parameters shall be adapted to the specific project situation.

[4] e.g. World Reference Base for Soil Resources (WRB) Reference Soil Groups (RSG)

8.1.3 | If other agricultural activities besides cover crops are introduced in a project (e.g., tillage change), interactions shall be considered by applying the same SOC quantification approaches (Approach 1, 2, or 3). If models are applied (Approach 2 or 3), they shall specifically cover all activities in the project scenario.

8.1.4 | For the project scenario, the eligible project area shall be stratified into MUs according to the criteria in Section 7 of the Soil Organic Carbon Framework Methodology. In addition, the following criteria shall be considered in stratification. Baseline strata with bare land shall be subdivided based on cover crop type and practices.

- Mineral soil type
- Tillage practices
- Specific crops (or crop rotations) and production period
- Productivity (e.g., net primary productivity or crop yield)
- Fallow (bare) period (relevant only if part of the project area lands remain uncovered for all or part of the year, e.g., due to environmental conditions preventing cover crops at the time)
- Cover crop period
- Cover crop type

For each stratum (MU), SOC measurements shall be performed (Approach 1) and/or model parameters shall be identified and verified (Approach 2 or 3).

8.1.5 | If a model is used to quantify project SOC (Approach 2), full transparency shall be provided on input data and parametrisation. Application of "black box" models is not allowed.

9| Uncertainty

9.1.1 | Calculation of uncertainty shall follow the rules and equations in the Soil Organic Carbon Framework Methodology.

9.1.2 | If no information on Standard Deviation (SD) or Standard Error (SE) is known for a parameter, SE of 50% of the parameter value shall be assumed. For the calculations of the upper and lower confidence intervals, a t-value of 3 shall be applied. Exceptions to this rule are accepted default values that are considered constant (e.g., physical conversion rates, global warming potentials).

10| Other Emissions

10.1 | Project Emissions

10.1.1 | Significant additional GHG emissions (>5% total) due to the project shall be accounted for. For this Activity Module, that explicitly includes emissions from cover crop seed production and transport, increased fertiliser input, fuel and electricity use, and other agrochemical emissions.

10.1.2 | As such emissions may differ between strata, calculation for this Activity Module shall follow the rules and equations described in Equations 1 through 8, which replace the area-wide calculation in Equations 12 through 18 of the Soil Organic Carbon Framework Methodology. They follow the same approach but expand calculation to include cover crop seed production and transport, and they allow application of different emission factors and quantities for different strata.

$$PE_{t-0} = \Delta FE_{t-0} + \Delta FU_{t-0} + \Delta SPT_{t-0} + \Delta AE_{t-0} \quad \text{(Eq. 1)}$$

Where:

PE_{t-0} = *emissions from project activities in the calculation period [tCO_2e]*
ΔFE_{t-0} = *emissions from increased fertiliser use in the calculation period [tCO_2e]*
ΔFU_{t-0} = *emissions from increased fuel and electricity use in the calculation period [tCO_2e]*
ΔSPT_{t-0} = *emissions from cover crop seed production and transport in the calculation period [tCO_2e]*
ΔAE_{t-0} = *other agrochemical emissions in the calculation period [tCO_2e]*

10.2 | Increased Nitrogen Fertiliser Input

10.2.1 | Emissions from increased nitrogen (N) fertiliser input in the project scenario as compared to the baseline scenario are calculated as follows. No differentiation is made between synthetic and organic N fertiliser. This equation shall not be applied for decreases in N fertiliser input, in which case ΔFE_{t-0} is considered 0. To account for reductions in fertiliser input (and the respective GHG emissions reductions), a separate Gold Standard methodology shall be applied.

$$\Delta FE_{t-0} = \sum_y \left[EF_{FE,y} \times \sum_{a=1}^{T} \left(FE_{PR,y,a} - FE_{BL,y} \right) \right] \quad \text{(Eq. 2)}$$

Where:

ΔFE_{t-0} = *emissions from increased fertiliser use in the calculation period [tCO_2e]. Must be ≥ 0 in this Activity Module (i.e. no accounting of reductions).*
$FE_{PR,y,a}$ = *N fertiliser input in stratum y under the project scenario in year a of the calculation period [kgN]*

$FE_{BL,y}$ = *mean annual N fertiliser input in stratum y under the baseline scenario [kgN]*

T = *number of years in the calculation period [yr]*

$EF_{FE,y}$ = *Conversion factor for emissions from N fertiliser in stratum y [tCO_2e kgN^{-1}]. IPCC 2019 aggregated default value[5] for EF_{FE} is 0.01. Disaggregated default values in IPCC 2019 Table 11.1 may be used if fertiliser inputs are known per fertiliser type.*

FE_{PR} and *FE_{BL}* shall be documented by the project developer. For *FE_{BL}*, mean annual input is calculated based on respective management records for five years prior to project start. If no adequate documentation can be provided, *FE_{BL}* shall be no more than 50% of *FE_{PR}*.

10.3 | Increased Combustion of Fossil Fuels and Electricity Use

10.3.1 | Additional CO_2 emissions from use of fossil fuel and electricity in the project (e.g., fuel used by farm machines due to a need for stronger tractors or additional passes to close/treat the surface; fuel/electricity for irrigation pumps) shall be accounted for, unless project developer can demonstrate that fossil fuel/electricity used in the project scenario is less than or does not differ significantly from fossil fuel/electricity used in the baseline, in which case *ΔFU_{t-0}* is considered 0.

$$\Delta FU_{t-0} = \sum_y \left[\sum_{a=1}^{T} \left(FU_{PR,y,a} - FU_{BL,y} \right) + \left(EU_{PR,y,a} - EU_{BL,y} \right) \right] \qquad \text{(Eq. 3)}$$

Where:

ΔFU_{t-0} = *emissions from increased fossil fuel and electricity use in the calculation period [tCO_2e]*

$FU_{PR,y,a}$ = *emissions from use of fossil fuels in stratum y under the project scenario in year a of the calculation period [tCO_2e]*

$FU_{BL,y}$ = *mean annual emissions from use of fossil fuels in stratum y under the baseline scenario [tCO_2e]*

$EU_{PR,y,a}$ = *emissions from use of electricity in stratum y under the project scenario in year a of the calculation period [tCO_2e]*

$EU_{BL,y}$ = *mean annual emissions from use of electricity in stratum y under the baseline scenario [tCO_2e]*

T = *number of years in the calculation period [yr]*

[5] IPCC 2019, Vol. 4 AFOLU, Table 11.1 (aggregated default value)

10.3.2 | FU_{PR} and FU_{BL} shall be documented by the project developer and generally calculated with the equation below, based on fuel consumption by machine type and fuel emission factor.

$$FU_{i,y,a} = \sum_{MT} FUL_{i,y,MT,a} \times FEF_{i,y,MT} \quad \text{(Eq. 4)}$$

Where:

$FU_{i,y,a}$ = *emissions from use of fossil fuels in stratum y in year a [$tCO_2e\ ha^{-1}$]*
$FUL_{i,y,MT,a}$ = *fuel consumption in stratum y by the machinery type MT used in year a [litres]*
$FEF_{i,y,MT}$ = *emissions factor for the fuel used in stratum y in machinery MT [$tCO_2e\ litres^{-1}$]*
MT = *machinery type (gasoline two-stroke, gasoline four-stroke, diesel)*
i = *formula used for baseline (i=BL) as well as project scenario (i=PR)*

For FU_{BL}, mean annual emissions are calculated based on respective management records for five years prior to project start. If this is not available, the amount of fuel combusted can be estimated using fuel efficiency of the vehicle (e.g., l/100 km, l/tonne-km, l/hour) and the appropriate unit of use for the selected fuel efficiency (e.g., kilometres [km] driven if efficiency is given in l/100 km). If no adequate documentation can be provided, FU_{BL} shall be no more than 50% of FU_{PR}.

Non-CO_2 GHG emissions caused by the use of fossil fuel from the project (such as management operations, machinery, etc.) are insignificant and may thus be neglected.

10.3.3 | EU_{PR} and EU_{BL} shall be documented by the project developer and generally calculated with the equation below, based on electricity consumption by appliance and respective emission factor. If electricity is generated on-site using fossil fuels (e.g., in diesel generators for irrigation pumps), emissions from fuel combustion should be calculated instead, following the approach described above.

$$EU_{i,y,a} = \sum_{SE} EUW_{i,y,SE,a} \times EEF_{i,y,SE} \quad \text{(Eq. 5)}$$

Where:

$EU_{i,y,a}$ = *emissions from electricity consumption in stratum y in year a [$tCO_2e\ ha^{-1}$]*
$EUW_{i,y,SE,a}$ = *electricity consumption in stratum y from source SE in year a [kWh]*
$EEF_{i,y,SE}$ = *emissions factor for the electricity used in stratum y in source SE [$tCO_2e\ kWh^{-1}$]*
SE = *electricity source type (grid, fossil fuel generator, etc)*

i = *formula used for baseline (i=BL) as well as project scenario (i=PR)*

For EU_{BL}, mean annual emissions are calculated based on respective management records for five years prior to project start. If no adequate documentation can be provided, EU_{BL} shall be no more than 50% of EU_{PR}.

10.4 | Cover Crop Seed Production and Transport

10.4.1 | As applicability conditions for this Activity Module do not allow cover crops in the baseline scenario, emissions from seed production and transport (SPT) in the baseline scenario are considered 0. Change in emissions SPT_{t-0} thus equals emissions from seed production and transport in the project scenario SBT_{PR}, calculated as follows:

$$\Delta SPT_{t-o} = \sum_y \left[\sum_{a=1}^{T} \left(SPT_{PR,y,a} \right) \right] \quad \text{(Eq. 6)}$$

10.4.2 | Annual project emissions from seed production and transport $SPT_{PR,y,a}$ are calculated based on amount of seed per crop for each stratum:

$$SPT_{PR,y,a} = \sum_c \left[\left(S_{PR,y,a,c} \times A_{PR,y} \right) \times \left(EF_{SP,y,c} + EF_{ST,y,c} \times DistST_{PR,y,a,c} \right) \right] \text{(Eq. 7)}$$

Where:

$SPT_{PR,y,a}$ = *Emissions from seed production and transport in stratum y in year a of the project scenario [tCO_2e]*

$S_{PR,y,a,c}$ = *Amount of seed for crop c applied in stratum y in year a of the project scenario [kg ha^{-1}]*

$A_{PR,y}$ = *Area in stratum y in the project scenario [ha]*

$EF_{SP,y,c}$ = *Emission factor for production of seed for crop c applied in stratum y in year a of the project scenario [tCO2e kg^{-1}]*

$EF_{ST,y,c}$ = *Emission factor for transport of seed for crop c applied in stratum y in year a of the project scenario [tCO2e km^{-1} kg^{-1}]*

$DistST_{PR,y,a,c}$ = *Transport distance for seed for crop c applied in stratum y in year a of the project scenario [km]*

Amount of seed per crop $S_{PR,y,a,c}$ per stratum y shall be monitored and documented for the project. If no detailed information is available for seed crops, specifically for pre-mixed seeds, conservative and documented expert opinion may be used to estimate average amounts for each cover crop species applied in the mix.

Emission factors for seed production per crop $EF_{SP,y,c}$ shall be documented for the project. If no specific emission factors are available for a crop type, conservative default emission factors may be applied (e.g., based

on emission factors or life cycle assessment (LCA) quantifications for related crops. For details, see the monitoring requirements for $EF_{SP,y,c}$ in Section 12).

Emission factors for seed transport per seed type $EF_{ST,y,c}$ shall be documented for the project (if not already covered in LCA calculation for $EF_{SP,y,c}$). National values specific to the transport means (vehicle type, capacity, etc.) shall be applied. If no national emission factors are available, default emission factors can be applied conservatively (e.g., using tools or emission factors published by the Greenhouse Gas Protocol[6]).

Seed transport distance from production to field ($DistST_{PR,y,a,c}$) shall be documented based on field locations for each stratum y using verifiable distance calculation, e.g., geographic information system (GIS)/map distances. Average distance in each stratum weighted by field size shall be used for calculation. If emission factor for seed production ($EF_{SP,y,c}$) already includes transportation (e.g., to distribution centers), the remaining transport distance to the fields shall be calculated for $Dist_{PR,y,a,c}$. If different transport types (air, sea, ground) are used, respective distances shall be calculated separately, and respective emission factors ($EF_{ST,t,0}$) shall be applied.

10.5 | Other Agrochemical Emissions

10.5.1 | Additional agrochemical emissions (*AE*) related to the project from increased use of agrochemicals, especially pesticides or non-N fertilisers, shall be accounted for unless the project developer can demonstrate that agrochemicals used in the project scenario are less than or do not differ significantly from agrochemicals used in the baseline, in which case ΔAE_{t-0} is considered 0.

10.5.2 | If use of agrochemicals (herbicides, pesticides) or non-N fertiliser is significantly higher in the project than in the baseline scenario, the project developer shall calculate respective emissions by using specific amounts and emission factors. Emission factors applied shall be based on manufacturer information or scientific sources.

$$\Delta AE_{t-0} = \sum_y \left[\sum_{a=1}^{T} \left(AE_{PR,y,a} - AE_{BL,y} \right) \right] \quad \text{(Eq. 8)}$$

Where:

[6] "Emission Factors from Cross-Sector Tools" (EF list) or "GHG Emissions from Transport or Mobile Sources" (calculation tool, results provided correspond to $EF_{FT,t}$*$Dist_{FT,t}$) published at https://ghgprotocol.org/calculation-tools#cross_sector_tools_id (link accessed June 2021).

ΔAE_{t-0} = *additional emissions from project activity in the calculation period [tCO_2e]*

$AE_{PR,y,a}$ = *other emissions in stratum y under the project scenario in year a of the calculation period [tCO_2e]*

$AE_{BL,y}$ = *other emissions (annual mean) in stratum y under the baseline scenario [tCO_2e]*

T = *number of years in the calculation period [yr]*

10.5.3 | AE_{PR} and AE_{BL} shall be documented for each emitter type (agrochemical) by the project developer and calculated with the equation below, based on emission type, underlying quantity, and respective emission factor.

$$AE_{i,y,a} = \sum_{ET} AQ_{i,y,ET,a} \times AEF_{i,y,ET} \quad \text{(Eq. 9)}$$

Where:

$AE_{i,y,a}$ = *emissions from use of other agrochemicals in stratum y in year a [tCO2e ha^{-1}]*

$AQ_{i,y,ET,a}$ = *quantity of agrochemicals in stratum y for emitter type ET applied in year a [kg]*

$AEF_{i,y,ET}$ = *emissions factor of the agrochemical used in stratum y (for emitter type ET) [tCO_2e kg^{-1}]*

ET = *emitter type (specific pesticide, fertiliser, or other agrochemical)*

i = *formula used for baseline (i=BL) as well as project scenario (i=PR)*

10.5.4 | For AE_{BL}, mean annual emissions are calculated based on respective management records for five years prior to project start. If no adequate documentation can be provided, AE_{BL} shall be no more than 50% of AE_{PR}.

11| Leakage

11.1.1 | Calculation of leakage shall follow the rules and equations in the Soil Organic Carbon Framework Methodology. If a reduction in yield is detected in a performance certification, it is assumed that the lost production capacity shall be made up for on land outside the project area. Emissions caused by such a shift shall be accounted for as leakage according to the equation in the Soil Organic Carbon Framework Methodology.

11.1.2 | Additional requirements: Under this Activity Module, leakage shall be assessed at stratum level. Instead of Equation 19 of the Soil Organic Carbon Framework Methodology, leakage shall thus be calculated for each stratum separately, using equation 10:

$$LK_{t-0} = \sum_y \left[\frac{CY_{min,y} - CY_{t,y}}{CY_{BL,y}} \times \bar{A}_{y,t}\right] \times \left(\Delta BC_{LA} + \Delta SOC_{LA,t-0} + \Delta FE_{LA,t-0} + \Delta FU_{LA,t-0}\right) \text{(Eq. 10)}$$

Where:

LK_{t-0} = emissions due to shift of production to non-project lands (leakage area) [tCO_2e]

$CY_{t,y}$ = crop yield in stratum y at time t (5 year average) [kg ha^{-1}]*

$CY_{min,y}$ = lowest crop yield in stratum y in any calculation period since project start (5 year average) [kg ha^{-1}]*

$CY_{BL,y}$ = crop yield in stratum y under the baseline scenario (5 year average) [kg ha^{-1}]*

$\bar{A}_{y,t}$ = eligible project area in stratum y (5-year average) [ha]*

ΔBC_{LA} = change in biomass carbon stocks in leakage area [tCO_2e ha^{-1}]

$\Delta SOC_{LA,t-0}$ = change in soil organic carbon stocks in leakage area [tCO_2e ha^{-1}]

$\Delta FE_{LA,t-0}$ = change in emissions from use of fertiliser in leakage area [tCO_2e ha^{-1}]

$\Delta FU_{LA,t-0}$ = change in emissions from fuel use in leakage area [tCO_2e ha^{-1}]

* *If the baseline period is extended to cover full rotation cycles, crop yield and stratum area shall be calculated as the average across an equal length period.*

12| Monitoring

12.1.1 |Monitoring approach and parameters in the Soil Organic Carbon Framework Methodology shall be followed. Also, the project developer shall collect and document evidence that this Activity Module's applicability conditions are met at all times.

12.1.2 |Additional requirements: The following parameters shall be monitored in this Activity Module, depending on the quantification approach selected. Where parameters listed below overlap with the Soil Organic Carbon Framework Methodology monitoring section, the following descriptions shall be applied under this Activity Module to ensure stratum-level quantification and appropriate data sources.

Data/Parameter:	$A_{PR,y}$
Unit	Ha
Description	Area in stratum y in the project scenario
Source of data	Farm records (GPS data, GIS files)
Value(s) applied	
Measurement procedures	Documentation allowing unambiguous identification and documenting area size at field level
Monitoring frequency	At project start; reviewed annually
QA/QC procedures	
Additional comments	Used in Equation 7

Data/Parameter:	$\bar{A}_{y,t}$
Unit	Ha
Description	Area in stratum y at time t (five-year average*)
Source of data	Farm records (GPS data, GIS files)
Value(s) applied	
Measurement procedures	Documentation allowing unambiguous identification and documenting area size at field level
Monitoring frequency	Annually (for calculation of five-year average*)
QA/QC procedures	
Additional comments	Used in Equation 10

* If the baseline period is extended to cover full rotation cycles, area shall be calculated as the average across an equal length period.

Data/Parameter:	$AQ_{i,y,ET,a}$
Unit	Km
Description	Quantity of agrochemicals in stratum y for emitter type ET applied in year a
Source of data	Farm records
Value(s) applied	
Measurement procedures	Documentation of quantity and type of non-N–fertiliser agrochemicals used for cover crops (e.g., for termination)
Monitoring frequency	Annually
QA/QC procedures	
Additional comments	Used in Equation 9

Data/Parameter:	$AEF_{i,y,ET}$
Unit	$tCO_2e\ kg^{-1}$
Description	Emissions factor of the agrochemical used in stratum y (for emitter type ET)
Source of data	Supplier information
Value(s) applied	
Measurement procedures	Supplier LCA information for production and transport If no supplier information is available, national or international default values or third-party emission factors (e.g., from applicable studies on respective crop emissions) may be applied.
Monitoring frequency	Annually
QA/QC procedures	
Additional comments	Used in Equation 9

Data/Parameter:	$CY_{BL,c,y}$
Unit	kg ha^{-1}
Description	Average annual crop yield for crop type c per ha in stratum y in the project area during the baseline period (five-year average)
Source of data	Farm records, e.g., field records, sales receipts
Value(s) applied	
Measurement procedures	Yield is recorded for each crop season and cumulated annually (as sum of each crop type). For the baseline, an average annual yield calculated across the five-year baseline period.
Monitoring frequency	Project start
QA/QC procedures	
Additional comments	This parameter replaces parameter CY_{BL} in the Soil Organic Carbon Framework Methodology (Equation 19).

Data/Parameter:	$CY_{t,y}$
Unit	kg ha^{-1}
Description	Average annual crop yield per ha in stratum y in the project area (five-year average*)
Source of data	Farm records, e.g., field records, sales receipts
Value(s) applied	
Measurement procedures	Yield is recorded for each crop season and cumulated annually (as sum of each crop type). Average annual yield is calculated for each stratum across the five-year reporting period. If cover crops are partially grazed or harvested (e.g., as feed or biomass crop), this yield may be included in $CY_{t,y}$ and, as relevant in quantification Approach 2 or 3, may be deducted from organic inputs to the soil (i.e., the respective model parameter). * If the baseline period is extended to cover full rotation cycles, crop yield shall be calculated as the average across an equal length period.
Monitoring frequency	Annually
QA/QC procedures	
Additional comments	Used in equation 10. This parameter replaces parameter CY_t in the Soil Organic Carbon Framework Methodology (Equation 19).

Data/Parameter:	$CY_{min,y}$
Unit	kg ha^{-1}
Description	Minimum annual crop yield per ha in stratum y since project start
Source of data	Farm records, e.g., field records, sales receipts
Value(s) applied	
Measurement procedures	Yield is recorded for each crop season and cumulated annually (as sum of each crop type). $CY_{min,y}$ represents lowest average annual yield per stratum since project start and serves as threshold to assess yield reduction.
Monitoring frequency	Annually
QA/QC procedures	
Additional comments	Used in Equation 8. This parameter replaces parameter CY_{min} in the Soil Organic Carbon Framework Methodology (Equation 19).

Data/Parameter:	$DistST_{PR,y,a,c}$
Unit	km
Description	Transport distance for seed for crop c applied in stratum y in year a of the project scenario
Source of data	
Value(s) applied	
Measurement procedures	Seed transport distance from production to field shall be documented based on field locations for each stratum y using verifiable distance calculation, e.g., GIS/map distances. Average distance in each stratum weighted by field size shall be used for calculation. If emission factor for seed production ($EF_{SP,y,c}$) already includes transportation (e.g., to distribution centers), the remaining transport distance to the fields shall be calculated for $Dist_{PR,y,a,c}$. If different transport types (air, sea, ground) are used, respective distances shall be calculated separately, and respective emission factors ($EF_{ST,t,0}$) shall be applied.
Monitoring frequency	Annually
QA/QC procedures	
Additional comments	Used in Equation 7

Data/Parameter:	$EF_{FE,y}$
Unit	tCO2e kgN-1
Description	Conversion factor for emissions from N fertiliser in stratum y
Source of data	IPCC 2019
Value(s) applied	IPCC 2019 aggregated default value for EF_{FE} is 0.01. Disaggregated default values in IPCC 2019 Table 11.1 may be used if fertiliser inputs are known per fertiliser type.
Measurement procedures	
Monitoring frequency	Project start
QA/QC procedures	
Additional comments	Used in Equation 2

Data/Parameter:	$EF_{SP,y,c}$
Unit	$tCO2e\ kg^{-1}$
Description	Emission factor for production of seed for crop c applied in stratum y in year a of the project scenario
Source of data	Seed producer information/product information
Value(s) applied	
Measurement procedures	If no specific emission factors are available for a crop, conservative default emission factors may be applied, e.g., emission factors from national sources, peer-reviewed scientific publications or factors based on LCA quantifications for related (commercial) crops with comparable management practices (i.e., fertiliser use and field management/tillage).
Monitoring frequency	Project start; updated annually
QA/QC procedures	The seed production emission factors shall be assessed by an expert who shall be part of the VVB team at project validation.
Additional comments	Used in Equation 7

Data/Parameter:	$EF_{ST,y,c}$
Unit	$tCO2e\ km^{-1}\ kg^{-1}$
Description	Emission factor for transport of seed for crop c applied in stratum y in year a of the project scenario
Source of data	National transport emission factors
Value(s) applied	
Measurement procedures	Documented for the project (if not already covered in LCA calculation for $EF_{SP,y,c}$) National values specific to the transport means (vehicle type, capacity, etc.) shall be applied. If no national emission factors are available, default emission factors can be applied conservatively, e.g., by using tools or emission factors published by the Greenhouse Gas Protocol: Emission Factors from Cross-Sector Tools (EF list) or GHG Emissions from Transport or Mobile Sources (calculation tool; results provided correspond to $EF_{FT,t}*Dist_{FT,t}$), published at https://ghgprotocol.org/calculation-tools#cross_sector_tools_id (link accessed June 2021). Uncertainty of factor applied shall be determined based on parameter source (e.g., scientific source for emission factor used in tools listed above) or, if not available, conservatively assumed to be 50%.
Monitoring frequency	Project start; reviewed annually
QA/QC procedures	
Additional comments	Used in Equation 7

Data/Parameter:	$EEF_{i,y,SE}$
Unit	$tCO_2e\ kWh^{-1}$

Description	Emissions factor for the electricity used in stratum y in source SE
Source of data	a) National GHG inventory sources such as: • U.S.: Emission Factors for Greenhouse Gas Inventories (epa.gov) EU: EMEP/EEA air pollutant emission inventory guidebook 2023 — European Environment Agency (europa.eu) and EMEP/EEA air pollutant emission inventory (europa.eu) b) If no national data is available, default emission factors in IPCC 2006, Volume 2, Chapter 3, Table 3.3.1 may be applied (taking into account listed uncertainties).
Value(s) applied	
Measurement procedures	
Monitoring frequency	Project start; reviewed annually for national updates
QA/QC procedures	
Additional comments	Used in Equation 5

Data/Parameter:	$EUW_{i,y,SE,a}$
Unit	kWh
Description	Electricity consumption in stratum y from source SE in year a
Source of data	Farm records
Value(s) applied	
Measurement procedures	1) Document electric equipment and power source used for cover cropping in each stratum. 2) Quantify electricity used for cover crop activity based on: a. Direct records (electricity documentation), or b. Duration of equipment use (hours) and power consumption per equipment type (kW).
Monitoring frequency	Use-based documentation, aggregated (sum) per year
QA/QC procedures	
Additional comments	Used in Equation 5

Data/Parameter:	$FE_{BL,y}$
Unit	kgN
Description	Mean annual N fertiliser input in stratum y under the baseline scenario
Source of data	Farm records (field level)
Value(s) applied	Average annual N input in stratum y, calculated across baseline period (five years)
Measurement procedures	
Monitoring frequency	Project start
QA/QC procedures	
Additional comments	Used in Equation 2

Data/Parameter:	$FE_{PR,y,a}$
Unit	kgN
Description	N fertiliser input in stratum y under the project scenario in year a
Source of data	Farm records (field level)
Value(s) applied	Sum of N inputs in stratum y in year a
Measurement procedures	
Monitoring frequency	Use-based; aggregated annually
QA/QC procedures	
Additional comments	Used in Equation 2

Data/Parameter:	$FEF_{i,y,MT}$
Unit	tCO_2e $liters^{-1}$
Description	Emissions factor for the fuel used in stratum y in machinery MT
Source of data	a) National GHG inventory sources such as: • U.S.: Emission Factors for Greenhouse Gas Inventories (epa.gov) • Canada: Emission_Factors.pdf (ec.gc.ca) • EU: EMEP/EEA air pollutant emission inventory guidebook 2023 — European Environment Agency (europa.eu) and EMEP/EEA air pollutant emission inventory (europa.eu) b) If no national data is available, default emission factors in IPCC 2006, Volume 2, Chapter 3, Table 3.3.1 may be applied (taking into account listed uncertainties).
Value(s) applied	
Measurement procedures	
Monitoring frequency	Project start; reviewed annually for national updates
QA/QC procedures	
Additional comments	Used in Equation 4

Data/Parameter:	$FUL_{i,y,MT,a}$
Unit	Liter
Description	Fuel consumption in stratum y by the machinery type MT used in year a
Source of data	Farm records
Value(s) applied	
Measurement procedures	1) Document machines and fuel type for equipment used for cover cropping in each stratum. 2) Document amount of equipment use for cover crops from: a. Direct records (fuel use), or b. Equipment usage (hours or distance) and fuel consumption (liters/hour or liters/km).
Monitoring frequency	Baseline: Project start Project: Use-based documentation, aggregated (sum) per year
QA/QC procedures	
Additional comments	Used in Equation 4

Data/Parameter:	$S_{PR,y,a,c}$
Unit	kg ha^{-1}
Description	Amount of seed for crop c applied in stratum y in year a of the project scenario
Source of data	Farm records
Value(s) applied	
Measurement procedures	Document for each cover crop type separately. If no detailed information is available for seed crops, specifically for pre-mixed seeds, conservative and documented expert opinion may be used to estimate average amounts for each cover crop species applied in the mix.
Monitoring frequency	Use-based documentation, aggregated (sum) per year
QA/QC procedures	
Additional comments	Used in Equation 7