Verified Carbon Standard

VCS Methodology

VM0042

METHODOLOGY FOR IMPROVED AGRICULTURAL LAND MANAGEMENT

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Sectoral Scope 14

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1 SOURCES

This methodology is based on the following methodologies:

- *VM0017 Adoption of Sustainable Agricultural Land Management*
- *VM0022 Quantifying N2O Emissions Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction*
- *VM0026 Sustainable Grassland Management*

This methodology uses the latest versions of the following CDM tools:

- *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*
- *Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands*
- *Tool for testing significance of GHG emissions in A/R CDM project activities*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This Agricultural Land Management (ALM) methodology provides procedures to estimate the greenhouse gas (GHG) emission reductions and removals resulting from the adoption of improved agricultural land management practices focused on increasing soil organic carbon (SOC) storage. The methodology quantifies net emissions of CO_2, CH_4, and N_2O from grower operations. The methodology is compatible with regenerative agriculture.

The baseline scenario assumes the continuation of pre-project agricultural management practices. For regions where an applicable performance benchmark has been approved by Verra[1], that benchmark must be applied as the baseline scenario. Otherwise, for each sample unit within the project area (e.g., for each field), practices applied in the baseline scenario are determined applying a 3-year historic look-back period to produce an annual schedule of activities (i.e., tillage, planting, harvest, and fertilization events) to be repeated over the first baseline period. Baseline emissions/stocks change are then modeled. The baseline scenario is

[1] Such performance benchmarks currently (as of the date of publication) do not exist but may be developed and approved by Verra in the future. If following Quantification Approach 1 (Measure and Model), the performance benchmark developed and approved by Verra will need to include a defined modeled approach that allows for validating model performance and prediction error for use in the project domain, based on the requirements presented in the "Model calibration, validation, and uncertainty guidance for the methodology for improved agricultural land management" document.

re-evaluated as required by the *VCS Standard*, and revised, if necessary, to reflect current agricultural production in the region.

Additionality is demonstrated by the adoption, at the project start date, of one or more changes in pre-existing agricultural management practices. A practice change constitutes adoption of a new practice (e.g., adoption of one or more of the practices covered in the categories included in the applicability conditions as well as the illustrative improved agricultural land management practices listed in Appendix 1), cessation of a pre-existing practice (e.g., stop tillage or irrigation), adjustment to a pre-existing practice, or some combination. Any quantitative adjustment (e.g., decrease in fertilizer application rate) must exceed 5% of the pre-existing value to demonstrate additionality.

The methodology provides a flexible approach to quantifying emission reductions and removals resulting from the adoption of improved agricultural land management practices under the following quantification approaches:

- **Quantification Approach 1:** Measure and Model – an acceptable model is used to estimate GHG flux based on edaphic characteristics and actual agricultural practices implemented, measured initial SOC stocks, and climatic conditions in sample fields.
- **Quantification Approach 2:** Measure and Re-measure – direct measurement is used to quantify changes in SOC stocks. This approach is relevant where models are unavailable or have not yet been validated or parameterized for a particular region, crop, or practice. Currently, Quantification Approach 2 cannot be used because a performance benchmark has not yet been developed.
- **Quantification Approach 3:** Calculation – CO_2 flux from fossil fuel combustion and N_2O and CH_4 fluxes, excluding CH_4 flux from methanogenesis, are calculated following *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* using equations contained in this methodology.

Quantification approach varies by emission/removal type. Approaches to quantification of contributing sources for CO_2, CH_4, and N_2O are listed in Table 5. Monitoring is conducted for both the baseline and project scenarios. If an applicable performance benchmark is not available, emission/stock changes in the baseline scenario are modeled using Quantification Approach 1, partly on the basis of one or more monitored input variables (e.g., temperature, precipitation) or calculated using Quantification Approach 3 as detailed in Table 5.

Table 1: Additionality and Crediting Baseline Methods

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Annual
A plant species that within one year completes life cycle, reproduces, and dies.

Improved agricultural land management practice
An agricultural practice yielding increased soil organic carbon storage or other climate benefit, involving a refinement to fertilizer application, water management/irrigation, tillage, residue management, crop planting and harvesting and/or grazing practices.

N-fixing species
Any plant species that associates with nitrogen-fixing microbes found within nodules formed on the roots, including but not limited to soybeans, alfalfa, and peas.

Organic nitrogen fertilizer
Any organic material containing nitrogen, including but not limited to animal manure, compost and sewage sludge.

Perennial
A plant species whose life cycle, reproduction and death extends across multiple years.

Professional agronomist
An individual with specialized knowledge, skill, education, experience, or training in crop and/or soil science.

Project domain
Set of conditions (including crop type, soil texture and climate) within which model application has been validated (see VMD0053 "Model Calibration and Validation Guidance for the Methodology for Improved Agricultural Land Management").

Sample point
Sample location of undefined area.

Sample unit
Defined area that is selected for measurement and monitoring, such as a field or sample point. Sample unit and sample field are used interchangeably in the methodology.

Schedule of Activities
Annual schedule of historical management/activity practices applied in the baseline scenario over the historic look-back period (i.e., tillage, planting, harvest, and fertilization events). These practices are based on data requirements of Box 1 repeated over the baseline period and apply

to relevant model input variables (see Tables 4 and 7) and parameters $FFC_{bsl,j,i,t}$, $P_{bsl,l,i,t}$, $Days_{bsl,l,i,t}$, $M_{bsl,SF,i,t}$, $M_{bsl,OF,i,t}$, and $MB_{g,bsl,i,t}$, etc.

Synthetic nitrogen fertilizer
Any fertilizer made by chemical synthesis (solid, liquid, gaseous) containing nitrogen (N). This may be a single nutrient fertilizer product (only including N), or any other synthetic fertilizer containing N, such as multi-nutrient fertilizers (e.g., N–P–K fertilizers) and 'enhanced-efficiency' N fertilizers (e.g., slow release, controlled release and stabilized N fertilizers).

Woody perennials
Trees and shrubs having a life cycle lasting more than two years, not including cultivated annual species with lignified tissues, such as cotton or hemp.

Year
A time period *t* equal to the portion of the monitoring period contained within a single calendar year. May be less than 365 days.

4 APPLICABILITY CONDITIONS

This methodology is global in scope and applies to a broad range of agricultural management project activities that increase soil organic carbon storage and/or decrease net emissions of CO2, CH4, and N2O from grower operations compared to the baseline scenario.

This methodology is applicable under the following conditions:

1. Projects must introduce or implement one or more new changes to pre-existing agricultural management practices which:
    - Reduce fertilizer (organic or inorganic) application;
    - Improve water management/irrigation;
    - Reduce tillage/improve residue management;
    - Improve crop planting and harvesting (e.g., improved agroforestry, crop rotations, cover crops); and/or
    - Improve grazing practices.

    A change constitutes adoption of a new practice (e.g., adoption of one of the illustrative improved agricultural land management practices listed in Appendix 1), cessation of a pre-existing practice (e.g., stop tillage or irrigation) or adjustment to a pre-existing practice that is expected to reduce GHG emissions and/or increase GHG removals. Any quantitative adjustment (e.g., decrease in fertilizer application rate) must exceed 5% of the pre-existing value.

    See Appendix 1 for additional details on these practices.

2. Project activities must be implemented on land that is either cropland or grassland at the project start date and remains cropland or grassland throughout the project crediting period (i.e., land use change is not eligible, including conversion from cropland to grassland and grassland to cropland).
3. The project area must not have been cleared of native ecosystems within the 10-year period prior to the project start date.
4. The project activity is not expected to result in a sustained reduction of greater than 5%[2] in productivity, as demonstrated by peer-reviewed and/or published studies on the activity in the region or a comparable region.
5. If the project activity involves the application of biochar, it must be produced using feedstock that would otherwise have been left to decay in aerobic or anaerobic conditions or been burned in an uncontrolled manner. Eligible feedstocks include one or more of the following categories of biomass:
    - Crop residues;
    - Material from pruning or thinning of woody vegetation (not including merchantable timber) in agricultural systems such as shade trees, orchards, windbreaks, stream buffers, silvopasture, or invasive removal on rangeland;
    - Off-cuts, sawdust, and other material produced as a by-product of forest management or harvesting operations;
    - Diseased trees or deadwood felled during plantation or woodland management; and/or
    - Residential, commercial, or industrial organic food or yard waste.

    There may not be any other carbon incentive awarded for the production of biochar applied on the project area.

This methodology is not applicable under the following conditions:

1. The project activity cannot occur on a wetland. Note that this condition does not exclude crops subject to artificial flooding where it can be demonstrated that crop cultivation does not impact the hydrology of any nearby wetlands.

Additional conditions where models are applied:

The methodology does not mandate the use of any specific model. Rather, this methodology is applicable where empirical or process-based models used to estimate stock change/emissions meet specific conditions. Models must be:

1. Publicly-available;

[2] 5% is the *VCS Methodology Requirements* threshold for emissions that can be considered *de minimis*.

2. Shown in peer-reviewed scientific studies to successfully simulate changes in soil organic carbon and trace gas emissions resulting from changes in agricultural management included in the project description;
3. Able to support repetition of the project model simulations. This includes clear versioning of the model use in the project, stable software support of that version, as well as fully reported sources and values for all parameters used with the project version of the model. Where multiple sets of parameter values are used in the project, full reporting includes clearly identifying the sources of varying parameter sets as well as how they were applied to estimate stock change/emissions in the project. Acceptable sources include peer-reviewed literature and statements from appropriate expert groups (i.e., that can demonstrate evidence of expertise with the model via authorship on peer-reviewed model publications or authorship of reports for entities supporting climate smart agriculture, such as FAO or a comparable organization), and must describe the data sets and statistical processes used to set parameter values (i.e., the parameterization or calibration procedure); and
4. Validated per datasets and procedures detailed in VMD0053 "Model Calibration and Validation Guidance for the Methodology for Improved Agricultural Land Management", with model prediction error calculated using datasets as detailed in the same module, using the same parameters or sets of parameters applied to estimate stock change/emissions in the project.

The same model version and parameters/parameter sets must be used in both the baseline and project scenarios. Model input data must be derived following guidance in Table 6 (Section 8.2) and Table 7 (Section 8.3). Model uncertainty must be quantified following guidance in Section 8.5. Models may be recalibrated or revised based on new data, or a new model may be applied, provided the above requirements are met.

5 PROJECT BOUNDARY

The spatial extent of the project boundary encompasses all lands subject to implementation of the proposed improved agricultural land management practice(s).

Selected carbon pools included in the project boundary in the baseline and project scenarios are listed in Table 2 below.

Table 1: Selected Carbon Pools in the Baseline and Project Scenario

Source	Included?	Justification/Explanation
Aboveground woody biomass	Yes / Optional	Aboveground woody biomass must be included where project activities may significantly reduce the pool compared to the baseline. In all other cases aboveground woody biomass is an optional pool. Where included it is calculated using the CDM A/R Tools *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities* and *Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands.*
Aboveground non-woody biomass	No	Carbon pool does not have to be included because it is not subject to significant changes, or potential changes are transient in nature, per the VCS rules.
Belowground woody biomass	Optional	This is an optional pool. Where included it is calculated using the CDM A/R Tools *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities* and *Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands.*
Belowground non-woody biomass	No	Carbon pool does not have to be included because it is not subject to significant changes, or potential changes are transient in nature, per the VCS rules.
Dead wood	No	Carbon pool is not included because it is not subject to significant changes or potential changes are transient in nature, per the VCS rules.
Litter	No	Carbon pool is not included, because it is not subject to significant changes or potential changes are transient in nature, per the VCS rules.
Soil organic carbon	Yes	Major carbon pool affected by project activity that is expected to increase in the project scenario.
Wood products	No	Carbon pool is optional for ALM project methodologies and may be excluded from the project boundary per the VCS rules.

GHG sources included in the project boundary in the baseline and project scenarios are listed in Table 3 below. Where the increase in greenhouse gas emissions from any project emissions or leakage source, and/or decreases in carbon stocks in carbon pools, is less than five percent of the total net anthropogenic GHG emission reductions and removals due to the project, such sources and pools may be deemed *de minimis* and may be ignored (i.e., their value may be accounted as zero). This and all subsequent references to *de minimis* demonstration are conducted via application of CDM A/R methodological *Tool for testing significance of GHG emissions in A/R CDM project activities.*[3]

Table 3: GHG Sources Included In or Excluded From the Project Boundary in the Baseline and With Project Scenario

Source	Gas	Included?	Justification/Explanation
Soil organic carbon	CO_2	Yes	Quantified as stock change in the pool, rather than an emissions source (see Table 2).
Fossil fuel	CO_2	S*	The sources of fossil fuel emissions are vehicles (mobile sources, such as trucks, tractors, etc.) and mechanical equipment required by the ALM activity.
Soil methanogenesis	CH_4	S*	
Enteric fermentation	CH_4	Yes	If livestock are present in the project or baseline scenario, CH_4 emissions from enteric fermentation must be included in the project boundary.
Manure deposition	CH_4	Yes	If livestock are present in the project or baseline scenario, CH_4 and N_2O emissions from manure deposition and management must be included in the project boundary.
	N_2O	Yes	
Use of nitrogen fertilizers	N_2O	Yes	If in the baseline scenario the project area would have been subject to nitrogen fertilization, or If nitrogen fertilization is greater in the with project scenario relative to the baseline scenario, N2O emissions from nitrogen fertilizers must be included in the project boundary.
Use of nitrogen fixing species	N_2O	Yes	If nitrogen fixing species are planted in the project, N_2O emissions from nitrogen fixing

[3] Since project activities may not result in a sustained reduction in productivity (including animal weight gains) or sustained displacement of any preexisting productive activity, feedlots are conservatively not included in the project boundary.

Source	Gas	Included?	Justification/Explanation
			species must be included in the project boundary.
Biomass burning	CO_2	Excluded	However, carbon stock decreases due to burning are accounted as a carbon stock change
Biomass burning	CH_4	S*	
	N_2O	S*	
Woody biomass	CO_2	S*	Quantified as stock change in the pool, rather than an emissions source (see Table 2).

S* Must be included where the project activity may significantly increase emissions compared to the baseline scenario and may be included where the project activity may reduce emissions compared to the baseline scenario.

6 BASELINE SCENARIO

Continuation of pre-project agricultural management practices is the most plausible baseline scenario. For each sample unit (e.g., for each field), practices applied in the baseline scenario are determined applying a historic look-back period to produce an annual schedule of activities to be repeated over the first baseline period. Baseline emissions/stocks change are then modeled or calculated. The crops and practices assumed in the baseline scenario are re-evaluated as required by the VCS rules and revised, if necessary, to reflect current agricultural production in the region.

Development of schedule of activities in the baseline scenario

For each sample unit, a schedule of activities in the baseline scenario will be determined by assessment of practices implemented during the period prior to the project start date. The interval over which practices are assessed, x years, must be a minimum of 3 years and include at least one complete crop rotation, where applicable. Where a crop rotation is not implemented in the baseline, x = 3 years.

For each year, t = -1 to t = -x, information on agricultural management practices must be determined, per the requirements presented in Table 4 below. Units for application rates will be based on either model (Quantification Approach 1) or default (Quantification Approach 3) input requirements. Guidance on sourcing qualitative and quantitative information is provided in Box 1.

Table 4: Minimum specifications on agricultural management practices for the baseline scenario

Agricultural management practice	Qualitative	Quantitative
Crop planting and harvesting	• Crop Type(s)	• Approximate date(s) planted (if applicable) • Approximate date(s) harvested / terminated (if applicable)
Nitrogen fertilizer application	• Manure (Y/N) • Compost (Y/N) • Synthetic N fertilizer (Y/N)	• Manure type application rate (if applicable) • Compost type application rate (if applicable) • N application rate in synthetic fertilizer (if applicable)
Tillage and/or residue management	• Tillage: (Y/N) • Crop residue removal	• Depth of tillage (if applicable) • Frequency of tillage (if applicable) • Percent of soil area disturbed (if applicable) • Percent of crop residue removed (if applicable)
Water management/irrigation	• Irrigation (Y/N) • Flooding (Y/N)	• Irrigation rate (if applicable)
Grazing practices	• Grazing (Y/N) • Animal type (if applicable)	• Animal stocking rate, i.e., number of animals and length of time grazing in a given area annually (if applicable)

In most cases, quantitative information is associated with related qualitative information (see Box 1). Thus, a negative response on a qualitative element would mean there is no quantitative information related to that practice, whereas a positive response on a qualitative element would then require quantitative information related to that practice.

The schedule of activities, beginning with year $t = -x$, will be applied in the baseline scenario, from $t = 1$ onward, repeating every x years through the end of the first baseline period.

The schedule of activities in the baseline scenario will be valid until reevaluation is required by the latest version of the *VCS Standard*. At the end of each baseline period, production of the commercial crop(s) in the baseline scenario will be re-evaluated. Published regional (sub-national) agricultural production data from within the 5-year period preceding the end of the current baseline period must be consulted.

Where there is evidence of continued production of the relevant commercial crop(s) using the same management practices, the baseline scenario will be valid as-is per the VCS rules, continuing with the previous schedule of activities. Where there is no evidence of continued production of the relevant commercial crop(s), a new schedule of agricultural management activities (evaluated against common practices in the region) will be developed on the basis of written recommendations for the sample field provided by an independent professional agronomist or government agricultural extension agent. Recommendations must provide sufficient detail to produce the minimum specifications on agricultural management practices for the baseline scenario as enumerated in Table 4 above. Where more than one value is documented in recommendations (e.g., where a range of application rates are prescribed in written recommendations), the principle of conservatism must be applied, selecting the value that results in the lowest expected emissions (or highest rate of stock change) in the baseline scenario.

Where the evidence is not field-specific, conservatively derived field-specific values must be supported by a documented method of field-specific values justifying the appropriateness of selection.

7 ADDITIONALITY

This methodology uses a project method for the demonstration of additionality.

The project proponent must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Methodology Requirements*.

In addition to the demonstration of regulatory surplus, project proponent(s) must:

1. Identify barriers that would prevent the implementation of a change in pre-existing agricultural practices; and,

2. Demonstrate that the adoption of the suite of proposed project activities is not common practice.

Further details on each of these steps are provided below.

Step 1: Identify barriers that would prevent the implementation of a change in pre-existing agricultural management practices

The project proponent must determine whether there are barriers (e.g., cultural practices and social norms, attitudes and beliefs) to the proposed change(s) in agricultural management expected to reduce GHG emissions and/or increase GHG removals that prevent the implementation of the change without the intervention of the project proponent and the resulting revenue from the sale of VCUs.

The project proponent must list and describe barriers to implementation of proposed changes to pre-project agricultural management practices to establish that the change would not occur if the project was not undertaken by the project proponent and registered as a VCS project. For example, cultural and/or social barriers related to averting risk in the face of uncertainty (Rodriguez et al. 2009)[4] as well as self-perceived capacity to implement changes (Singh et al. 2016)[5] have been shown to inhibit practice change in the agricultural sector. Further, trust in technical assistance providers is critical for spreading adoption of changes (Carolan 2006)[6] among other factors, such as access to information and increased social networking among growers (Roco et al. 2014)[7].

Demonstration of cultural and/or social barriers must be supported by peer-reviewed and/or published studies. Such barriers may include traditional knowledge or lack thereof, laws and customs, market conditions and lack of motivating incentives to change practices, including, but not limited to:

- Traditional equipment and technology;
- Barriers associated with whether growers believe they can feasibly adopt new practices, implications of decisions, and their attitudes towards risk;
- Barriers associated with openness to new ideas and the grower perceptions of the magnitude of the change; and
- Barriers associated with grower identity.

Step 2: Demonstrate that the adoption of the suite of proposed project activities is not common practice

The project proponent must determine whether the proposed project activity or suite of activities[8] are common practice in each region included within the project spatial boundary. Common practice is defined as greater than 20% adoption.[9] To demonstrate that a project activity, or suite of activities, is not common practice, the project proponent must show that the weighted average adoption rate of the three (or more) predominant[10] proposed project

[4] Rodriguez, JM, Molnar, JJ, Fazio, RA, Sydnor, E, Lowe, MJ. 2009. Barriers to adoption of sustainable agriculture practices: Change agent perspectives. *Renewable Agriculture and Food Systems* 24: 60-71.

[5] Singh, C, Dorward, P, Osbahr, H. 2016. Developing a holistic approach to the analysis of farmer decision-making: Implications for adaptation policy and practice in developing countries. Land Use Policy 59: 329-343.

[6] Carolan, MS. 2006. Social change and the adoption and adaptation of knowledge claims: Whose truth do you trust in regard to sustainable agriculture? *Agriculture and Human Values* 23: 325-339.

[7] Roco, L, Engler, A, Bravo-Ureta, B, Jara-Rojas, R. 2014. Farm level adaptation decisions to face climatic change and variability: Evidence from Central Chile. Environmental Science & Policy 44: 86-96.

[8] The suite of activities refers to all activities implemented across the aggregated project. It does not refer to the activities implemented on each individual farm.

[9] Following the 20% common practice threshold in the CDM *Methodological tool: Common practice* https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-24-v1.pdf.

[10] Determined based on the extent of the project area (acres or hectares).

activities within the project spatial boundary is below 20%.[11] Therefore, in projects where existing activity (e.g., reduced tillage) adoption rates are >20% the project must include a proportionally higher ratio of other activities with lower adoption rates (e.g., cover crops, improved fertilizer management) to bring the weighted average of proposed project activities below 20%. An individual activity with an existing adoption rate in the relevant region below 20% isalways considered additional. However, an individual activity with an existing adoption rate greater than 20% may only be considered additional through the assessment of the weighted average adoption rate for all project lands within that region.

Categories of project activities for the demonstration of common practice may be defined according to the categories in the evidence provided, or to the categories outlined in Table 4.

Evidence must be provided in the form of publicly available information contained in:

1. Agricultural census or other government (e.g., survey) data;
2. Peer-reviewed scientific literature;
3. Independent research data; or
4. Reports or assessments compiled by industry associations.

The highest-quality available evidence source appropriate to the project must be used. The project area should be divided for the purpose of the common practice demonstration to the state or provincial level (or equivalent 2nd order jurisdiction) in the country(ies) where the project is being developed. If supporting evidence is not available at the state/provincial level (e.g., in developing countries) aggregated data or evidence at a country or regional level may be used, with justification.

When evidence on the proposed project activity, or suite of activities, in the region is not available from any of these sources, the project proponent may obtain a signed and dated attestation statement from a qualified independent local expert (e.g., agricultural extension agent, accredited agronomist) stating that the proposed project activity, or suite of activities, is not common practice in the region.

To calculate the weighted average adoption rate in each region covered by the project area Equation 1 must be applied:

Equation 1

$$AR = ((EA_{ai} \times PA_{ai}) + (EA_{a2} \times PA_{a2}) + \cdots + (EA_{an} \times PA_{an})\ ;\ where$$

$$PA_{a1} = \frac{Area_{a1}}{(Area_{a1} + Area_{a2} + \cdots + Area_{an})}$$

[11] If a project is planning to only implement two activities, common practice must be assessed based on the weighted average of those two activities. If only one activity is implemented, common practice must be assessed solely based on that activity’s adoption rate (i.e., the adoption rate of that activity must be below 20%).

$$PA_{a2} = \frac{Area_{a2}}{(Area_{a1} + Area_{a2} + \cdots + Area_{an})}$$

$$PA_{an} = \frac{Area_{an}}{(Area_{a1} + Area_{a2} + \cdots + Area_{an})}$$

Where:

AR	weighted average adoption rate in region; %
EA_{a1}	existing adoption rate of largest (i.e., size of land area) most common proposed project activity in region; %
EA_{a2}	existing adoption rate of second largest most common proposed project activity in region; %
EA_{an}	existing adoption rate of the *n* largest most common proposed project activity in region; %
PA_{a1}	ratio of proposed project-level adoption of Activity $_{a1}$ relative to proposed project-level adoption of Activity $_{a1}$ + Activity$_{a2}$ + … + Activity$_{an}$ in region; unitless
PA_{a2}	ratio of proposed project-level adoption of Activity $_{a2}$ relative to proposed project-level adoption of Activity $_{a1}$ + Activity$_{a2}$ + … + Activity$_{an}$ in region; unitless
PA_{an}	ratio of proposed project-level adoption of Activity $_{an}$ relative to proposed project-level adoption of Activity $_{a1}$ + Activity$_{a2}$ + … + Activity$_{an}$ in region; unitless
$Area_{a1}$	area of proposed project-level adoption of Activity $_{a1}$ in region; hectares or acres
$Area_{a2}$	area of proposed project-level adoption of Activity $_{a2}$ in region; hectares or acres
$Area_{an}$	area of proposed project-level adoption of Activity $_{an}$ in region; hectares or acres
n	project activity category

A project proponent may include areas where more than one project activity will be implemented on the same land (e.g., reduced tillage plus cover crops). Evidence on existing adoption rates for the combined (two or more) activities should be used to calculate the weighted average adoption rate of the proposed combined activities. Where evidence on existing adoption rates for the combined activities is not available, the project proponent may multiply the existing adoption rates (i.e., pre-project) of the individual activities to estimate the combined activity adoption rate.[12] For example, with a statewide existing adoption rate of 40% for reduced-tillage and 10% for cover-cropping, the existing adoption rate to be applied (in the weighted average calculation above) for lands combining (stacking) these two activities would be 4% (i.e., 40% x 10%).

If Step 1 and Step 2 are satisfied, the proposed project activity is additional.

[12] In practice, this encourages "stacking" of new activities to enhance GHG reductions and/or removals compared to implementing only one new activity on a given area or farm.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Summary

This methodology provides a flexible approach to quantifying emission reductions and removals resulting from the adoption of improved agricultural land management practices in the project compared to the baseline scenario. Baseline and project emissions are defined in terms of flux of CH_4, and N_2O and CO_2 in units of tonnes of CO_2e per unit area per monitoring period. Within each sample unit, stock changes in each included pool are treated on a per unit area basis in accounting procedures, while changes in emissions are treated as the total change in emissions from each source per sample unit, prior to generating an areal average for the project in Section 8.5. Where a monitoring period crosses multiple calendar years, the equations quantify emission reductions by year (as defined in Section 3) in order to appropriately define vintage periods.

Approaches to quantification of contributing sources for CO_2, CH_4 and N_2O are listed in Table 5. For a given pool/GHG source, projects must preferentially set the baseline scenario equal to the performance benchmark where an applicable performance benchmark exists. Where more than one quantification approach is allowable for a given gas and source, more than one approach may be used, provided that within a given area of the project the same approach is used for both the project and baseline scenarios.

Table 5: Summary of Allowable Quantification Approaches

GHG/Pool	Source	Quantification Approach 1: Measure and Model*	Quantification Approach 2: Measure and Remeasure	Quantification Approach 3: Default
CO_2	Soil organic carbon	X	X	
	Fossil fuel			X
	Woody biomass**			
CH_4	Soil methanogenesis	X		
	Enteric fermentation			X
	Manure deposition			X
	Biomass burning			X

GHG/Pool	Source	Quantification Approach 1: Measure and Model*	Quantification Approach 2: Measure and Remeasure	Quantification Approach 3: Default
N_2O	Use of nitrogen fertilizers	X		X
	Use of nitrogen fixing species	X		X
	Manure deposition			X
	Biomass burning			X

* Approach 1 may only be used if a valid model is available (see model requirements in VMD0053 "Model Calibration and Validation Guidance for the Methodology for Improved Agricultural Land Management").

** If included in the project boundary, woody biomass is calculated using the CDM A/R Tools *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities* and *Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands.*

For each pool/source, subdivisions of the project area using different quantification approaches must be stratified and accounted separately. A project may switch between allowable quantification approaches for a given source during the project crediting period, provided that the same approach is used for both the project and baseline scenario. The quantification approaches are defined as follows:

1. **Quantification Approach 1: Measure and Model**

   An acceptable model is used to estimate GHG flux based on actual agricultural practices implemented, measured initial SOC stocks, and climatic conditions in sample units.

2. **Quantification Approach 2: Measure and Remeasure**

   Relevant where models are unavailable or have not yet been validated or parameterized. The baseline is set equal to a performance benchmark. Quantification Approach 2 is only applicable to SOC.

   Note – Currently Quantification Approach 2 cannot be used because a performance benchmark does not exist. Interested stakeholders would be responsible for developing the performance benchmark in accordance with VCS Guidance for Standardized Methods*. The creation of a performance benchmark will require a revision to the methodology.*

3. **Quantification Approach 3: Calculation**

   GHG flux is calculated following the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* using equations contained in this methodology.

Where a given activity is not practiced in the baseline or project, resulting in an effective input of zero for any equation element in this methodology, that equation element is not required.

For projects employing Quantification Approach 1 for the quantification of SOC stock changes, the subsequent direct SOC measurement will be used in the same manner as in the first year of the project, as the input to the model simulation for that year. The output SOC stock from that simulation would then be compared to the output SOC stock from the simulation of the prior monitoring period to determine the SOC stock change, and thereby incorporating any adjustment (i.e., “true-up”) based on the direct measurement.

8.2 Baseline Emissions

Quantification Approach 1

The baseline is modeled for each sample unit. Where an applicable performance benchmark exists, the baseline is equal to the performance benchmark. The model serves to project stock change/emissions resulting from the schedule of agricultural management activities taking place in the baseline scenario (derived above). Further guidance on biophysical model inputs is elaborated in Table 6.

Table 6: Guidance on collection of biophysical model inputs for the baseline scenario, where required by the model selected

Model Input Category	Timing	Approach
Soil organic carbon stock and bulk density (initial)	Determined *ex ante*	Directly measured at *t=0* or (back-) modeled to *t =0* from measurements collected within +/-5 years of *t =0,* or determined for *t*=0 via emerging technologies (e.g., remote sensing) with known uncertainty. See parameter table for $SOC_{wp,i,t=0}$.
Soil properties (other than bulk density and soil organic carbon)	Determined *ex ante*	Directly measured or determined from published soil maps, with known uncertainty. Estimates from direct measurements must satisfy the following: • Derived from representative (unbiased) sampling • Accuracy of measurements is ensured through adherence to best practices.

Model Input Category	Timing	Approach
Climate variables (e.g., precipitation, temperature)	Continuously monitored *ex ante*	Measured for each model-specific meteorological input variable at its required temporal frequency (e.g., daily) model prediction interval. Measurements are taken at the closest continuously-monitored weather station, not exceeding 50 km of the sample field, or from a synthetic weather station (e.g., PRISM[13]).

Quantification Approach 2

Where a Verra-approved applicable performance benchmark exists, the baseline is equal to the performance benchmark.

Note – Currently Quantification Approach 2 cannot be used because a performance benchmark does not exist. Interested stakeholders would be responsible for developing the performance benchmark in accordance with VCS Guidance for Standardized Methods*. The creation of a performance benchmark will require a revision to the methodology.*

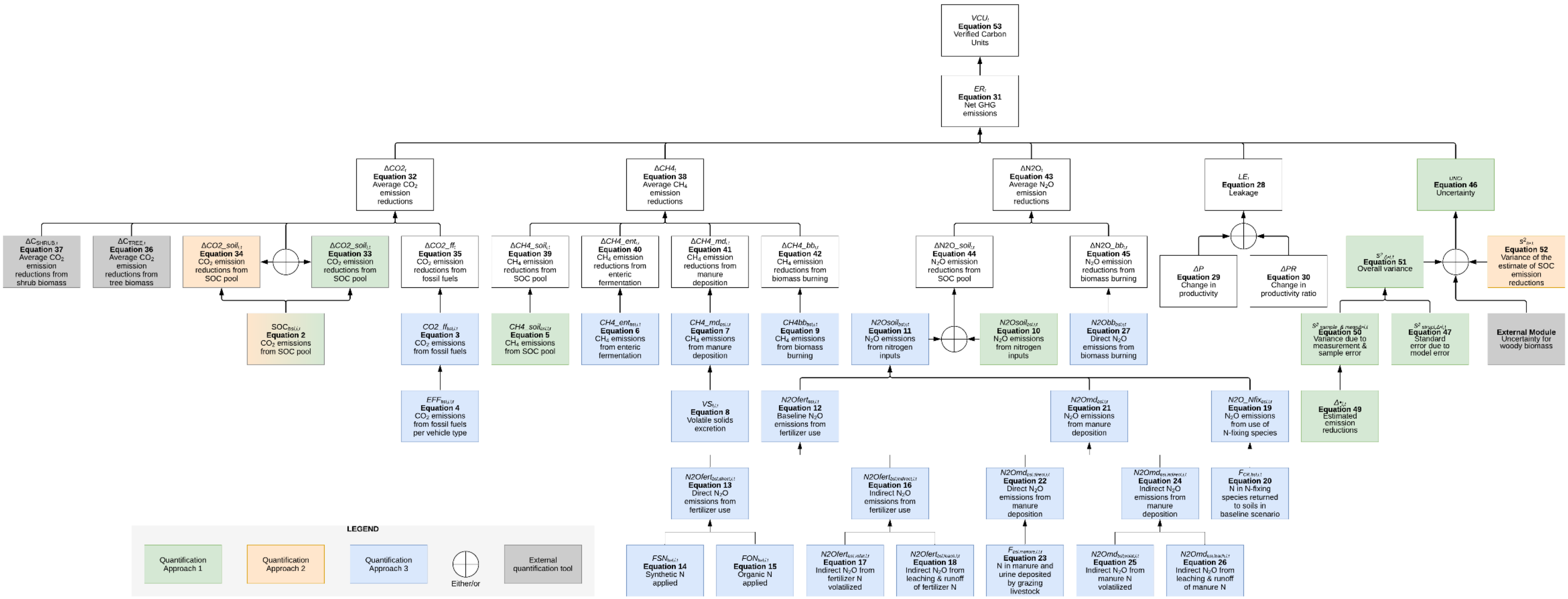
Quantification Approach 3

The baseline is calculated for each sample field using the equations below. Emissions resulting from the schedule of agricultural management activities taking place in the baseline scenario (derived above) are estimated using default emission factors and data determined for each sample field at validation.

Calculation flow is summarized in Figure 1 below:

[13] https://climatedataguide.ucar.edu/climate-data/prism-high-resolution-spatial-climate-data-united-states-maxmin-temp-dewpoint

Figure 1. Equation map of the Methodology for Improved Agricultural Land Management



8.2.1 Soil Organic Carbon Stocks

Soil organic carbon stocks are estimated under Quantification Approach 1, using Equation 2 below:

Equation 2

$$SOC_{bsl,i,t} = ⨍SOC_{,bsl,i,t}$$

Where:

$SOC_{bsl,i,t}$	Carbon stocks in the soil organic carbon pool in the baseline scenario for sample unit *i* at the end of period *t;* tCO_2e/unit area
$⨍SOC_{,bsl,i,t}$	Modeled soil organic carbon stocks in the baseline scenario for sample unit *i* at the end of period *t*; tCO_2e/unit area
i	Sample unit

8.2.2 Change in Carbon Stocks in Aboveground and Belowground Woody Biomass

If carbon stocks in aboveground and belowground woody biomass are included in the project boundary per Table 3, change in carbon stocks in trees ($\Delta C_{TREE,bsl,i,t}$) and shrubs ($\Delta C_{SHRUB,bsl,i,t}$) in the baseline for sample unit *i* in year *t* are calculated using the CDM A/R Tools *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities* and *Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands.*

8.2.3 Carbon Dioxide Emissions from Fossil Fuel Combustion

If carbon dioxide emissions from fossil fuel are included in the project boundary per Table 3, they are quantified in the baseline scenario under Quantification Approach 3, using Equation 3 and Equation 4 below.

Parameter $CO2\_ff_{bsl,i,t}$ is estimated using the following equation:

Equation 3

$$CO2ff_{bsl,i,t} = (\sum_{j=1}^{J} EFF_{bsl,j,i,t})/A_i$$

Where:

$CO2\_ff_{bsl,i,t}$	Carbon dioxide emissions from fossil fuel combustion in the baseline scenario for sample unit *i* in year *t*; tCO_2e/unit area

$EFF_{bsl,j,i,t}$	Carbon dioxide emissions from fossil fuel combustion in the baseline scenario in fossil fuel vehicle/equipment type *j* for sample unit *i* in year *t;* tCO_2e
A_i	Area of sample unit *i*; unit area
j	Type of fossil fuel (gasoline or diesel)
i	Sample unit

The parameter $EFF_{bsl,j,i,t}$ is estimated using the following equation:

Equation 4

$$EFF_{bsl,j,i,t} = FFC_{bsl,j,i,t} \times EF_{CO2,j}$$

Where:

$EFF_{bsl,j,i,t}$	Carbon dioxide emissions from fossil fuel combustion in the baseline scenario in vehicle/equipment type *j* for sample unit *i* in year *t*; tCO_2e
$FFC_{bsl,j,i,t}$	Consumption of fossil fuel type *j* for sample unit *i* in year *t*; liters
$EF_{CO2,j}$	Emission factor for the type of fossil fuel *j* combusted; tCO_2e/liter
j	Type of fossil fuel (gasoline or diesel)
i	Sample unit

8.2.4 Methane Emissions from the Soil Organic Carbon Pool

If methane emissions from the soil organic pool are included in the project boundary per Table 3, they are quantified in the baseline scenario under Quantification Approach 1 using Equation 5.

Equation 5

$$CH4soil_{bsl,i,t} = GWP_{CH4} \times ʄCH4soil_{bsl,i,t}$$

Where:

$CH4soil_{bsl,i,t}$	Methane emissions from soil organic carbon pool in the baseline scenario for sample unit *i* in year *t*; tCO_2e/unit area
$ʄCH4soil_{bsl,i,t}$	Modeled methane emissions from the soil organic carbon pool in the baseline scenario for sample unit *i* in year *t*; tCH_4e/unit area
GWP_{CH4}	Global warming potential for CH_4
i	Sample unit

8.2.5 Methane Emissions from Livestock Enteric Fermentation

If methane emissions from livestock enteric fermentation are included per Table 3, they are quantified in the baseline scenario under Quantification Approach 3 using Equation 6.

Equation 6

$$CH4ent_{bsl,i,t} = (\frac{GWP_{CH4} * \sum_{l=1}^{L} P_{bsl,l,i,t} * Days_{bsl,l,i,t} * EF_{ent,l}}{1000 * 365})/A_i$$

Where:

$CH4\_ent_{bsl,i,t}$	Methane emissions from livestock enteric fermentation in the baseline scenario for sample unit *i* in year *t*; tCO_2e/unit area
$P_{bsl,l,i,,t}$	Population of grazing livestock in the baseline scenario of type *l* in sample unit *i* in year *t;* head
$Days_{bsl,l,i,t}$	Average grazing days per head in the baseline scenario for each livestock type *l* in sample unit *i* in year *t;* days
$EF_{ent,l}$	Enteric emission factor for livestock type *l*; kg CH_4/(head * year)
GWP_{CH4}	Global warming potential for CH_4
A_i	Area of sample unit *i*; unit area
l	Type of livestock
i	Sample unit
365	days per year
1000	kg per tonne

8.2.6 Methane Emissions from Manure Deposition

If methane emissions from manure deposition are included in the project boundary per Table 3, they are quantified in the baseline scenario under Quantification Approach 3 using Equation 7 and Equation 8.

Equation 7

$$CH4_{md\,bsl,i,t} = \frac{GWP_{CH4} * \sum_{l=1}^{L}(P_{bsl,l,i,t} * VS_{l,i,t} * Days_{bsl,l,i,t} * EF_{CH4,md,l})}{10^6 * A_i}$$

Where:

$CH4\_md_{bsl,i,t}$	Baseline CH_4 emissions from manure deposition in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
GWP_{CH4}	Global warming potential for CH_4
$P_{bsl,l,i,,t}$	Population of grazing livestock in the baseline scenario of type *l* for sample unit *i* in year *t*; head
$VS_{l,i,t}$	Average volatile solids excretion per head for livestock type *l* in sample unit *i* in year *t*; kg volatile solids/(head * day)$Days_{bsl,l,i,t}$ Average grazing days per head in the baseline scenario for each livestock type *l* in sample unit *i* in year *t;* days
$EF_{CH4,md,l}$	Emission factor for methane emissions from manure deposition for livestock type *l*; g CH4/(kg volatile solids)
A_i	Area of sample unit *i*; unit area
l	Type of livestock
i	Sample unit
10^6	Grams per tonne

Equation 8

$$VS_{l,i,t} = VS_{rate,l} * \frac{W_{bsl,l,i,t}}{1000}$$

Where:

$VS_{l,i,t}$	Annual volatile solids excretion of livestock type *l* for sample unit *i* in year *t*; kg volatile solids/(head * day)
$VS_{rate,l}$	Default volatile solids excretion rate for livestock type *l*; kg volatile solids/(1000 kg animal mass * day)
$W_{bsl,l,i,t}$	Average weight in the baseline scenario of livestock type *l* for sample unit *i* in year *t*; kg animal mass/head
1000	Kg per 1000 kg
l	Type of livestock
i	Sample unit

8.2.7 Methane Emissions from Biomass Burning

If methane emissions from biomass burning are included in the project boundary per Table 3, they are quantified in the baseline scenario under Quantification Approach 3 using Equation 9.

Equation 9

$$CH4bb_{bsl,i,t} = (\frac{GWP_{CH4} * \sum_{c=1}^{C} MB_{bsl,c,i,t} * CF_c * EF_{c,CH4}}{10^6})/A_i$$

Where:

$CH4\_bb_{bsl,i,t}$	Methane emissions in the baseline scenario from biomass burning for sample unit *i* in year *t*; t CO_2e/unit area
$MB_{bsl,c,i,t}$	Mass of agricultural residues of type *c* burned in the baseline scenario for sample unit *i* in year *t*; kilograms
CF_c	Combustion factor for agricultural residue type *c;* proportion of pre-fire fuel biomass consumed
$EF_{c,CH4}$	Methane emission factor for the burning of agricultural residue type *c*; g CH_4/kg dry matter burnt
GWP_{CH4}	Global warming potential for CH_4
A_i	Area of sample unit *i*; unit area
c	Type of agricultural residue
i	Sample unit
10^6	Grams per tonne

8.2.8 Nitrous Oxide Emissions from Nitrogen Fertilizers and Nitrogen-Fixing Species

Nitrous oxide emissions due to nitrification/denitrification include direct and indirect emissions from nitrogen fertilizers and direct emissions from nitrogen-fixing species. If nitrous oxide emissions due to nitrogen inputs to soils from nitrogen fertilizers and nitrogen-fixing species are included in the project boundary per Table 3, they are quantified in the baseline scenario under Quantification Approach 1 or Quantification Approach 3. If quantified under Quantification Approach 1, Equation 10 is used. If quantified under Quantification Approach 3, Equation 11 is used.

Quantification Approach 1

Direct and indirect nitrous oxide emissions due to nitrogen inputs to soils (nitrogen fertilizers, manure deposition, and nitrogen-fixing species) in the baseline scenario are quantified as:

Equation 10

$$N2Osoil_{bsl,i,t} = GWP_{N2O} \times fN2Osoil_{bsl,i,t}$$

Where:

$N2Osoil_{bsl,i,t}$	Direct and indirect nitrous oxide emissions due to nitrogen inputs to soils in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$fN2Osoil_{bsl,i,t}$	Modeled nitrous oxide emissions from soil (summed across the reporting period for sample unit *i*); t N_2O/unit area
GWP_{N2O}	Global warming potential for N_2O
i	Sample unit

Quantification Approach 3

Nitrous oxide emissions due to nitrogen inputs to soils in the baseline scenario estimated applying the following equation:

Equation 11

$$N2Osoil_{bsl,i,t} = N2Ofert_{bsl,i.t} + N2Omd_{bsl,i,t} + N2ONfix_{bsl,i,t}$$

Where:

$N2Osoil_{bsl,i,t}$	Nitrous oxide emissions due to nitrogen inputs to soils in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$N2Ofert_{bsl,i,t}$	Nitrous oxide emissions due to fertilizer use in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$N2Omd_{bsl,i,t}$	Nitrous oxide emissions due to manure deposition in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$N2ONfix_{bsl,i,t}$	N_2O emissions due to the use of N-fixing species in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
i	Sample unit

Under Quantification Approach 3, if nitrous oxide emissions due to fertilizer use are included in the project boundary per Table 3, they are quantified in the baseline scenario using Equation 12, Equation 13, Equation 14, Equation 15, Equation 16, Equation 17, and Equation 18.

Equation 12

$$N2Ofert_{bsl,i,t} = N2Ofert_{bsl,direct,i,t} + N2Ofert_{bsl,indirect,i,t}$$

Where:

$N2Ofert_{bsl,i,t}$	Nitrous oxide emissions due to fertilizer use in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area

$N2Ofert_{bsl,direct,i,t}$	Direct nitrous oxide emissions due to fertilizer use in the baseline scenario for sample unit *i* in year *t;* t CO_2e/unit area
$N2Ofert_{bsl,indirect,i,t}$	Indirect nitrous oxide emissions due to fertilizer use in the baseline scenario for sample unit *i* in year *t;* t CO_2e/unit area
i	Sample unit

Under Quantification Approach 3, direct nitrous oxide emissions due to fertilizer use in the baseline scenario are quantified in Equation 13, Equation 14, and Equation 15.

Equation 13

$$N2Ofert_{bsl,direct,i,t} = ((FSN_{bsl,i,t} + FON_{bsl,i,t}) \times EF_{Ndirect} \times 44/28 \times GWP_{N2O})/A_i$$

Equation 14

$$FSN_{bsl,i,t} = \sum_{SF} M_{bsl,SF,i,t} \times NC_{bsl,SF}$$

Equation 15

$$FON_{bsl,i,t} = \sum_{OF} M_{bsl,OF,i,t} \times NC_{bsl,OF}$$

Where:

$N2Ofert_{bsl,direct,i,t}$	Direct nitrous oxide emissions due to fertilizer use in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$FSN_{,bsl,i,t}$	Baseline synthetic N fertilizer applied for sample unit *i* in year *t*; t N
$FON_{,bsl,i,t}$	Baseline organic N fertilizer applied for sample unit *i* in year *t*; t N
$M_{bsl,SF,i,t}$	Mass of baseline N containing synthetic fertilizer type *SF* applied for sample unit *i* in year *t;* t fertilizer
$M_{bsl,OF,i,t}$	Mass of baseline N containing organic fertilizer type *OF* applied for sample unit *i* in year *t*; t fertilizer
$NC_{bsl,SF}$	N content of baseline synthetic fertilizer type *SF* applied; t N/t fertilizer
$NC_{bsl,OF}$	N content of baseline organic fertilizer type *OF* applied; t N/t fertilizer
$EF_{Ndirect}$	Emission factor for nitrous oxide emissions from N additions from synthetic fertilizers, organic amendments and crop residues; t N2O-N/t N applied
SF	Synthetic N fertilizer type
OF	Organic N fertilizer type

A_i	Area of sample unit *i*; unit area
GWP_{N2O}	Global warming potential for N_2O
i	Sample unit
$44/28$	Ratio of molecular weight of N_2O to molecular weight of N applied to convert N_2O-N emissions to N_2O emissions

Under Quantification Approach 3, indirect nitrous oxide emissions due to fertilizer use in the baseline scenario are quantified in Equation 16, Equation 17 and Equation 18.

Equation 16

$$N2Ofert_{bsl,indirect,i,t} = (N2Ofert_{bsl,volat,i,t} + N2Ofert_{bsl,leach,i,t})/A_i$$

Equation 17

$$N2Ofert_{bsl,volat,i,t} = \left[\left(FSN_{bsl,i,t} \times Frac_{GASF}\right) + \left(FON_{bsl,i,t} \times Frac_{GASM}\right)\right] \times EF_{Nvolat} \times 44/28 \times GWP_{N2O}$$

Equation 18

$$N2Ofert_{bsl,leach,i,t} = \left(FSN_{bsl,i,t} + F_{ONbsl,i,t}\right) \times Frac_{LEACH} \times EF_{Nleach} \times 44/28 \times GWP_{N2O}$$

Where:

$N2O\_fert_{bsl,indirect,i,t}$	Indirect nitrous oxide emissions due to fertilizer use in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$N2O\_fert_{bsl,volat,i,t}$	Indirect nitrous oxide emissions produced from atmospheric deposition of N volatilized due to fertilizer use for sample unit *i* in year *t*; t CO_2e
$N2O\_fert_{bsl,leach,i,t}$	Indirect nitrous oxide emissions produced from leaching and runoff of N, in regions where leaching and runoff occurs, due to fertilizer use for sample unit *i* in year *t*; t CO_2e.
$FSN_{bsl,i,t}$	Baseline synthetic N fertilizer applied for sample unit *i* in year *t*; t N
$FON_{bsl,i,t}$	Baseline organic N fertilizer applied for sample unit *i* in year *t*; t N
$Frac_{GASF}$	Fraction of all synthetic N added to soils that volatilizes as NH_3 and NO_x; dimensionless
$Frac_{GASM}$	Fraction of all organic N added to soils and N in manure and urine deposited on soils that volatilizes as NH_3 and NO_x; dimensionless
$Frac_{LEACH}$	Fraction of N added (synthetic or organic) to soils and in manure and urine deposited on soils that is lost through leaching and runoff, in regions where leaching and runoff occurs; dimensionless. For wet

	climates[14] or in dry climate regions where irrigation (other than drip irrigation) is used, a value of 0.24 is applied. For dry climates, a value of zero is applied.
EF_{Nvolat}	Emission factor for nitrous oxide emissions from atmospheric deposition of N on soils and water surfaces; t N2O-N /(t NH3-N + NOx-N volatilized)
EF_{Nleach}	Emission factor for nitrous oxide emissions from leaching and runoff; t N2O-N / t N leached and runoff
A_i	Area of sample unit *i*; unit area
GWP_{N2O}	Global warming potential for N_2O
i	Sample unit
$44/28$	Ratio of molecular weight of N_2O to molecular weight of N applied to convert N_2O-N emissions to N_2O emissions

If nitrous oxide emissions due to the use of N-fixing species are included in the project boundary per Table 3, they are quantified in the baseline scenario under Quantification Approach 3 using Equation 19 and Equation 20.

Equation 19

$$N2O\_Nfix_{bsl,i,t} = (F_{CR,bsl,i,t} \times EF_{Ndirect} \times \frac{44}{28} \times GWP_{N2O})/A_i$$

Where:

$N2O\_Nfix_{bsl,i,t}$	Nitrous oxide emissions due to the use of N-fixing species in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$F_{CR,bsl,,i,t}$	Amount of N in N-fixing species (above and below ground) returned to soils in the baseline scenario for sample unit *i* in year *t*; t N
$EF_{Ndirect}$	Emission factor for nitrous oxide emissions from N additions from synthetic fertilizers, organic amendments and crop residues; t N2O-N/t N applied
A_i	Area of sample unit *i*; unit area
GWP_{N2O}	Global warming potential for N_2O
i	Sample unit
$44/28$	Ratio of molecular weight of N_2O to molecular weight of N applied to convert N_2O-N emissions to N_2O emissions

[14] Wet climates occur in temperate and boreal zones where the ratio of annual precipitation : potential evapotranspiration > 1, and tropical zones where annual precipitation > 1000 mm. Dry climates occur in temperate and boreal zones where the ratio of annual precipitation : potential evapotranspiration < 1, and tropical zones where annual precipitation < 1000 mm.

Equation 20

$$F_{CR,bsl,i,t} = \sum_{g=1}^{G} MB_{g,bsl,i,t} \times N_{content,g}$$

Where:

$F_{CR,bsl,,i,t}$	Amount of N in N-fixing species (above and below ground) returned to soils in the baseline scenario in sample unit *i* in year *t*; t N
$MB_{g,bsl,i,t}$	Annual dry matter, including aboveground and below ground, of N-fixing species *g* returned to soils for sample unit *i* in year *t*; t dm
$N_{content,g}$	Fraction of N in dry matter for N-fixing species *g*; t N/t dm
g	Type of N-fixing species
i	Sample unit

8.2.9 Nitrous Oxide Emissions from Manure Deposition

If nitrous oxide emissions due to manure deposition are included in the project boundary per Table 3, they are quantified in the baseline scenario under Quantification Approach 3 using Equation 21, Equation 22, Equation 23, Equation 24, and Equation 25.

Equation 21

$$N2Omd_{bsl,i,t} = N2Omd_{bsl,direct,i,t} + N2Omd_{bsl,indirect,i,t}$$

Where:

$N2O\_md_{bsl,i,t}$	Nitrous oxide emissions due to manure deposition in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$N2O\_md_{bsl,direct,i,t}$	Direct nitrous oxide emissions due to manure deposition in the baseline scenario for sample unit *i* in year *t;* t CO_2e/unit area
$N2O\_md_{bsl,indirect,i,t}$	Indirect nitrous oxide emissions due to manure deposition in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
i	Sample unit

Direct nitrous oxide emissions due to manure deposition in the baseline scenario are quantified using Equation 22 and Equation 23.

Equation 22

$$N2Omd_{bsl,direct,i,t} = (\sum_{l=1}^{L} F_{bsl,manure,l,i,t} \times EF_{N2O,md,l} \times 44/28 \times GWP_{N2O})/A_i$$

Equation 23

$$F_{bsl,manure,l,i,t} = 1000 \times \left[\left(P_{bsl,l,i,t} \times Nex_l\right) \times MS_{bsl,l,i,t}\right]$$

Where:

$N2O\_md_{bsl,direct,i,t}$	Direct nitrous oxide emissions due to manure deposition in the baseline scenario for sample unit *i* in year *t;* t CO_2e/unit area
$F_{bsl,manure,l,i,t}$	Amount of nitrogen in manure and urine deposited on soils by livestock type *l* in sample unit *i* in year *t*; t N
$P_{bsl,l,i,t}$	Baseline population of livestock type *l* for sample unit *i* in year *t*; head
Nex_l	Average annual nitrogen excretion per head of livestock type *l*; kg N/head/year
$EF_{N2O,md,l}$	Emission factor for nitrous oxide from manure and urine deposited on soils by livestock type *l*; kg N_2O-N/kg N input
GWP_{N2O}	Global warming potential for N_2O
$MS_{bsl,l,I,t}$	Baseline fraction of total annual N excretion for each livestock type *l* for sample unit *i* in year *t* that is deposited on the project area; %
A_i	Area of sample unit *i*; unit area
l	Type of livestock
i	Sample unit
44/28	Ratio of molecular weight of N_2O to molecular weight of N applied to convert N_2O-N emissions to N_2O emissions

Indirect nitrous oxide emissions due to manure deposition in the baseline scenario are quantified under Quantification Approach 3 using Equation 24, Equation 25, and Equation 26.

Equation 24

$$N2Omd_{bsl,indirect,i,t} = (N2O_m d_{bsl,volat,i,t} + N2O_m d_{bsl,leach,i,t})/A_i$$

Equation 25

$$N2Omd_{bsl,volat,i,t} = F_{bsl,manure,l,i,t} \times Frac_{GASM} \times EF_{Nvolat} \times \frac{44}{28} \times GWP_{N2O}$$

Equation 26

$$N2Omd_{bsl,leach,i,t} = F_{bsl,manure,l,i,t} \times Frac_{LEACH} \times EF_{Nleach} \times \frac{44}{28} \times GWP_{N2O}$$

Where:

$N2O\_md_{bsl,indirect,i,t}$	Indirect nitrous oxide emissions due to manure deposition in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$N2O\_md_{bsl,volat,i,t}$	Indirect nitrous oxide emissions produced from atmospheric deposition of N volatilized due to manure deposition for sample unit *i* in year *t*; t CO_2e
$N2O\_md_{bsl,leach,i,t}$	Indirect nitrous oxide emissions produced from leaching and runoff of N, in regions where leaching and runoff occurs, as a result of manure deposition for sample unit *i* in year *t.* Equal to 0 where annual precipitation is less than potential evapotranspiration, unless irrigation is employed; t CO_2e
$F_{bsl,manure,l,i,t}$	Amount of nitrogen in manure and urine deposited on soils by livestock type *l* in sample unit *i* in year *t*; t N/unit area
$Frac_{GASM}$	Fraction of all organic N added to soils and N in manure and urine deposited on soils that volatilizes as NH_3 and NO_x; dimensionless
EF_{Nvolat}	Emission factor for nitrous oxide emissions from atmospheric deposition of N on soils and water surfaces; t N2O-N /(t NH3-N + NOx-N volatilized
$Frac_{LEACH}$	Fraction of all organic N added to soils and N in manure and urine deposited on soils that is lost through leaching and runoff, in regions where leaching and runoff occurs; dimensionless. For wet climates[15] or in dry climate regions where irrigation (other than drip irrigation) is used, a value of 0.24 is applied. For dry climates, a value of zero is applied.
EF_{Nleach}	Emission factor for nitrous oxide emissions from leaching and runoff; t N2O-N / t N leached and runoff
A_i	Area of sample unit *i*; unit area
GWP_{N2O}	Global warming potential for N_2O
l	Type of livestock
i	Sample unit

8.2.10 Nitrous Oxide Emissions from Biomass Burning

Nitrous emissions from biomass burning in the baseline scenario are quantified under Quantification Approach 3.

[15] Wet climates occur in temperate and boreal zones where the ratio of annual precipitation : potential evapotranspiration > 1, and tropical zones where annual precipitation > 1000 mm. Dry climates occur in temperate and boreal zones where the ratio of annual precipitation : potential evapotranspiration < 1, and tropical zones where annual precipitation < 1000 mm.

Parameter $N2O\_bb_{bsl,i,t}$ is estimated using the following equation:

Equation 27

$$N2Obb_{bsl,i,t} = \left(\frac{GWP_{N2O} \times \sum_{c=1}^{C} MB_{bsl,c,i,t} \times CF_c \times EF_{c,N2O}}{10^6}\right)/A_i$$

Where:

$N2O\_bb_{bsl,i,t}$	Nitrous oxide emissions in the baseline scenario from biomass burning for sample unit *i* in year *t*; t CO_2e/unit area
$MB_{bsl,c,i,t}$	Mass of agricultural residues of type *c* burned in the baseline scenario for sample unit *i* in year *t*; kilograms
CF_c	Combustion factor for agricultural residue type *c*; proportion of pre-fire fuel biomass consumed
$EF_{c,N2O}$	Nitrous oxide emission factor for the burning of agricultural residue type *c*; g N_2O/kg dry matter burnt
A_i	Area of sample unit *i*; unit area
GWP_{N2O}	Global warming potential for N_2O
i	Sample unit
10^6	Grams per tonne

8.3 Project Emissions

Stock change/emissions resulting from agricultural management activities taking place in the project scenario are either calculated or modeled on the basis of monitored inputs. The estimation of emissions of CO_2, CH_4, and N_2O in the project scenario from included sources must follow approaches provided in Table 1 and using the same equations in Section 8.1. For all equations, the subscript *bsl* must be substituted by *wp* to make clear that the relevant values are being quantified for the project scenario. Further, as per Section 8.4.1, if livestock are included in the baseline, the minimum value allowed for the project is equal to the average value from the historical baseline period.

Quantification Approach 1

Model inputs must be collected following guidance in Table 7.

Table 7: Guidance on collection of model inputs for the project scenario, where required by the model selected

Model Input Category	Timing	Approach
Soil organic carbon stock and bulk density	Determined at project start (re-measured every 5 years or less)	Directly measured or estimated via emerging technologies (e.g., remote sensing) with known uncertainty, every 5 years or less. See parameter table for $SOC_{wp,i,t}$.
Soil properties (other than bulk density and soil organic carbon)	Determined *ex ante*	Measured or determined from published soil maps with known uncertainty. Estimates from direct measurements must: ● Derived from representative (unbiased) sampling ● Accuracy of measurements is ensured through adherence to best practices (to be determined by the project proponent and outlined in the monitoring plan)
Climate variables (e.g., precipitation, temperature)	Continuously monitored *ex post*	Measured for each model-specific meteorological input variable at its required temporal frequency (e.g., daily) model prediction interval. Measurements are taken at the closest continuously-monitored weather station, not exceeding 50 km of the sample field, or from a synthetic weather station (e.g., PRISM[16]).

[16] https://climatedataguide.ucar.edu/climate-data/prism-high-resolution-spatial-climate-data-united-states-maxmin-temp-dewpoint

Model Input Category	Timing	Approach
Agricultural management activities (as identified following procedures in VMD0053 "Model Calibration and Validation Guidance for the Methodology for Improved Agricultural Land Management", referencing categories of practices outlined in applicability condition 1)	Monitored *ex post*	Required model inputs related to agricultural management practices will be monitored and recorded for each project year, *t*. Information on agricultural management practices will be monitored via consultation with, and substantiated with a signed attestation from, the farmer or landowner of the sample unit. Any quantitative information (e.g., discrete or continuous numeric variables) on agricultural management practices must be supported by one or more forms of documented evidence pertaining to the selected sample field and relevant monitoring period (e.g., management logs, receipts or invoices, farm equipment specifications). Units for quantitative information will be based on model input requirements.

Quantification Approach 2

Quantification Approach 2 is applied for estimation of emissions from soil organic carbon stocks only. Soil organic carbon stocks in the project scenario ($SOC_{wp,i,t}$) are directly measured in each sample field.

Note – Currently Quantification Approach 2 cannot be used because a performance benchmark does not exist.

Quantification Approach 3

Project emissions are calculated for each sample field using applicable default values and any monitored parameters.

Woody Biomass

Aboveground woody biomass must be included where project activities may significantly reduce the pool compared to the baseline. In all other cases aboveground woody biomass is an optional pool. Where included it is calculated using the CDM A/R Tools Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities and Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands.

8.4 Leakage

Improved ALM projects can result in leakage through new application of manure from outside the project area (i.e., manure applied in the project from outside of the project area, that was not previously applied in the historical baseline period), productivity declines, and/or the displacement of livestock outside of the project boundary. Guidance on how to account for each of these types of leakage is provided below.

8.4.1 Accounting for Leakage from New[17] Application of Manure from Outside the Project Area

If manure is applied in the project that was not applied in the historical baseline period, there is a risk of activity shifting leakage. To account for this type of leakage, a deduction must be applied unless:

1. The manure applied in the project is produced on-site from farms within the project area;
2. The manure can be documented to have been diverted from an anaerobic lagoon;[18] or
3. The deduction represents the portion of the manure carbon which remains on the project area without degrading during the project term and which would have otherwise been stored in agricultural land outside of the project area. Equation 28 estimates the SOC increase from imported manure application activities, reducing the total amount of carbon applied to 12% per a global manure-C retention coefficient sourced from Maillard and Angers (2014).

Equation 28

$$LE_t = \sum_l \left(M\_manure_{prj,l,t} \times CC_{prj,l,t} \times 0.12 \times \frac{44}{12} \right)$$

Where:

LE_t	Leakage in year *t*; t CO_2e
$M\_manure_{prj,l,t}$	Mass of manure applied as fertilizer on the project area from livestock type *l* in year *t*; tonnes
$CC_{prj,l,t}$	Carbon content of manure applied as fertilizer on the project area from livestock type l in year *t*; fraction

[17] In this context, “new” refers to manure application to fields which did not have manure applied during the historical baseline period.

[18] Where manure is diverted for field application rather than storage in an uncontrolled, anaerobic lagoon, the avoided methane emissions will far outweigh the SOC impacts. However, this only applies in cases where the manure is diverted to field application prior to lagoon storage.

0.12	Fraction of manure carbon expected to remain in the soils on the project area by the end of the project term (Maillard and Angers, 2014); fraction
$\frac{44}{12}$	Conversion from carbon to carbon dioxide equivalent; t C/t CO_2e

8.4.2 Accounting for Leakage from Livestock Displacement

To avoid crediting emission reductions from livestock displacement (i.e., lowering of CH_4 and N_2O emissions within the project area relative to the baseline, by reducing the number of livestock within the project boundary), the number of livestock in the project scenario must not be lower than the number of livestock in the historic baseline period. Thus, if livestock displacement occurs, the CH_4 and N_2O emissions associated with livestock must continue to be counted in the project scenario (in Equations 5, 6, 7, 20, 21, 22, 23, 24 and 25) to account for potential emissions leakage.

8.4.3 Accounting for Leakage from Productivity Declines

Market leakage is likely to be negligible because the land in the project scenario remains in agricultural production. Further, producers are unlikely to implement and maintain management practices that result in productivity declines, since their livelihoods depend on crop harvests as a source of income. Nevertheless, to ensure leakage is not occurring, the following steps must be completed every 10 years:

Step 1: Demonstrate that the productivity of each crop/livestock product has not declined by more than 5% in the project scenario by comparing:

1. Average with-project productivity (excluding years with extreme[19] weather events) of each crop/livestock product to average pre-project productivity of the same crop/livestock product using the following equation:

Equation 29

$$\Delta P = \left(\frac{P_{wp,p} - P_{bsl,p}}{P_{bsl,p}}\right) \times 100$$

Where:

ΔP	Change in productivity; percent

[19] Extreme weather events are defined as temperature, drought or precipitation events falling in the upper or lower tenth percentile of historical multi-year records for the project location (NOAA). Furthermore, tropical storms affecting the project location (e.g., hurricanes, typhoons and cyclones) are considered extreme weather events, as is any time a weather-related insurance claim is awarded.

$P_{wp,p}$	Average productivity for product p during the project period; productivity per hectare or acre
$P_{bsl,p}$	Average productivity for product p during the historical baseline period; productivity per hectare or acre
p	crop/livestock product

Or

2. The ratio of average baseline productivity to regional productivity at time t to the average ratio of project productivity to regional productivity at time t + 10 years, by crop/livestock product, using regional data from government (e.g., USDA Actual Production History (APH) data), industry, published, academic or international organization (e.g., FAO) sources.[20]

Equation 30

$$\Delta PR = \left(\frac{P_{wp,p}}{RP_{wp,p}} - \frac{P_{bsl,p}}{RP_{bsl,p}}\right) \times 100$$

Where:

ΔPR	Change in productivity ratio per hectare or acre
$P_{wp,p}$	Average productivity for product p during the project period
$P_{bsl,p}$	Average productivity for product p during the historical baseline period
$RP_{wp,p}$	Average regional productivity for product p during the same years as the project period
$RP_{bsl,p}$	Average regional productivity product p during the same years as the historical baseline period
p	crop/livestock product

With project productivity averages must be based on data collected in the previous 10 years. In other words, productivity averages cannot include data that is more than 10 years old. If productivity has improved, stayed constant or declined by less than 5% for a crop/livestock

[20] Note – Using this approach, a productivity decline of 10% in the project would be acceptable as long as a corresponding productivity decline of 10% was also observed in the regional data. This ensures that external factors such as reduced rainfall that can impact productivity in a region are fairly accounted for. Further, this approach prevents producers whose baseline productivity is lower than regional averages due to lack of access to inputs (e.g., agrochemicals), knowledge or some other factor from being unfairly penalized.

product, no further action is needed. If a reduction in productivity of greater than 5% is observed in one or more crop/livestock product, complete step 2 for these products.

Step 2: Determine whether the crop/livestock productivity decline was caused by a short-term change in productivity, by repeating the calculation in step 1 excluding all data inputs from the first three years of project implementation on a farm. If the with-project productivity of the crop/livestock product with the first three years removed is within 5% of the baseline productivity of the same crop/livestock product, no further action is needed[21]. If a reduction in productivity of greater than 5% is still observed in one or more crop/livestock product(s), complete step 3 for these products.

Step 3: Determine whether the productivity decline is limited to a certain combination of factors by stratifying the analysis by:

1. Practice change category,
2. Practice change category combinations,
3. Crop type,
4. Soil type, and/or
5. Climatic zone.

If the productivity decline is limited to a certain combination of factors, then that combination becomes ineligible for future crediting. For example, if a 10% decline in corn yields was observed and through stratification it was shown that the yield decline was linked to fertilizer rate reductions, then rate reduction practices on corn fields would no longer be eligible for future crediting. If the project proponent is unable to isolate the source(s) of leakage through stratification then the entire crop/livestock product becomes ineligible for future crediting.

8.5 Net GHG Emission Reductions and Removals

Net GHG emission reductions and removals are quantified as:

Equation 31

$$ER_t = (A_0 \times (\overline{\Delta CO2_t} + \overline{\Delta CH4_t} + \overline{\Delta N2O_t}) - LE_t) \times (1 - UNC_t)$$

Where:

ER_t	Estimated net GHG emissions reductions and removals in year *t*; t CO_2e
A_0	Project area*;* unit area
$\overline{\Delta CO2_t}$	Areal average[22] carbon dioxide emission reductions in year *t*; t CO_2e/unit area

[21] Initial implementation of improved ALM practices may lead to some declines in productivity as the producer adjusts their operation. By demonstrating that more recent years are within the 5% threshold, Step 2 shows that producers have overcome any early productivity declines.

[22] A bar over a symbol means an *areal-average* of that quantity (after summing over time and, if applicable, over depth).

$\overline{\Delta CH4_t}$	Areal average methane emission reductions in year *t*; t CO_2e/unit area
$\overline{\Delta N2O_t}$	Areal average nitrous oxide emission reductions in year *t*; t CO_2e/unit area
LE_t	Leakage in year *t*, equal to zero; t CO_2e
UNC_t	Uncertainty deduction in year *t*; fraction between 0 and 1

8.5.1 Carbon dioxide emission reductions ($\overline{\Delta CO2_t}$)

See parameter tables in Section 9.2 for derivation of $\overline{\Delta}_{\bullet,t}$ and $\overline{\bullet}_t$

Carbon dioxide emission reductions are quantified as:

Equation 32

$$\overline{\Delta CO2_t} = \overline{\Delta \mathrm{CO2\_soil}_t} + \overline{\Delta CO2\_ff_t} + \overline{\Delta C_{TREE,t}} + \overline{\Delta C_{SHRUB,t}}$$

Where:

$\overline{\Delta CO2_t}$	Areal average carbon dioxide emission reductions in year *t*; t CO_2e/unit area
$\overline{\Delta \mathrm{CO2\_soil}_t}$	Areal average carbon dioxide emission reductions from soil organic carbon pool in year *t*; t CO_2e/unit area
$\overline{\Delta CO2\_ff_t}$	Areal average carbon dioxide emission reductions from fossil fuel combustion in year *t*; t CO_2-e/unit area
$\overline{\Delta C_{TREE,t}}$	Areal average carbon dioxide emission reductions from tree biomass in year *t*; t CO_2-e/unit area
$\overline{\Delta C_{SHRUB,t}}$	Areal average carbon dioxide emission reductions from shrub biomass in year *t*; t CO_2-e/unit area

Carbon dioxide emission reductions from the soil organic carbon pool for sample unit *i* in year *t* are quantified for Quantification Approach 1 as:

Equation 33

$$\Delta CO2\_soil_{i,t} = (SOC_{wp,i,t} - SOC_{wp,i,t-1}) - (SOC_{bsl,i,t} - SOC_{bsl,i,t-1})$$

Where:

$\Delta CO2\_soil_{i,t}$	Carbon dioxide emission reductions from soil organic carbon pool for sample unit *i* in year *t*; t CO_2e /unit area
$SOC_{wp,i,t}$	Carbon stocks in the soil organic carbon pool in the project scenario for sample field *i* at the end of year *t*; t CO_2e /unit area
$SOC_{wp,i,t-1}$	Carbon stocks in the soil organic carbon pool in the project scenario for sample field *i* at the end of year *t-1*; t CO_2e /unit area
$SOC_{bsl,i,,t}$	Carbon stocks in the soil organic carbon pool in the baseline scenario for sample field *i* at the end of year *t*; t CO_2e/unit area
$SOC_{bsl,i,,t-1}$	Carbon stocks in the soil organic carbon pool in the baseline scenario for sample field *i* at the end of year *t-1*; t CO_2e/unit area

i	Sample unit

The initial SOC is the same in both the baseline and project scenarios at the outset of the project (i.e., $SOC_{wp,i,0} = SOC_{bsl,i,0}$); as a result, the first calculation of Equation 33 on sample unit *i* simplifies to $SOC_{wp,i,t} - SOC_{bsl,i,t}$.

For Quantification Approach 2, carbon dioxide emission reductions from the soil organic carbon pool for sample unit *i* in year *t* are compared to a baseline stock change that is equal to the performance benchmark[23]:

Equation 34

$$\Delta CO2\_soil_{i,t} = (SOC_{wp,i,t} - SOC_{wp,i,t\_previous}) - \left(SOC_{bsl,i,t} - SOC_{bsl,i,t\_previous}\right)$$

Where:

$\Delta CO2\_soil_{i,t}$	Estimated carbon dioxide emission reductions from soil organic carbon pool for sample unit *i* at the end of year *t*; t CO_2e/unit area
$SOC_{wp,i,t}$	Estimated carbon stocks in the soil organic carbon pool in the project scenario for sample field *i* at the end of year *t*; t CO_2e/unit area
$SOC_{wp,i,t\_previous}$	Estimated carbon stocks in the soil organic carbon pool in the project scenario for sample field *i* at the previous measurement year, *t_previous*; t CO_2e/unit area
$SOC_{bsl,i,t}$	Estimated carbon stocks in the soil organic carbon pool in the baseline scenario for sample field *i* at the end of year *t*; t CO_2e/unit area
$SOC_{bsl,i,t\_previous}$	Estimated carbon stocks in the soil organic carbon pool in the baseline scenario for sample field *i* at the previous measurement year, *t_previous*; t CO_2e/unit area
i	Sample unit

Where the period between time *t* and time *t_previous* spans multiple calendar years, the project proponent shall pro-rate the results of Equation 34 across the relevant vintages according to the number of days in the monitoring period contained within each vintage. For example, if the total stock change is measured across exactly three calendar years, then one third of the stock change would be attributed to each vintage.

Carbon dioxide emission reductions from fossil fuel combustion are quantified as:

Equation 35

$$\Delta CO2\_ff_{i,t} = CO2\_ff_{bsl,i,t} - CO2\_ff_{wp,i,t}$$

[23] Performance benchmarks for demonstration of the crediting baseline currently (as of the date of publication) do not exist. Such performance benchmarks may be established through a revision to this methodology following requirements in the most current versions of the VCS Standard and VCS Methodology Requirements.

Where:

$\Delta CO2\_ff_{i,t}$	Carbon dioxide emission reductions from fossil fuel combustion for sample unit *i* in year *t*; t CO_2e/unit area
$CO2\_ff_{bsl,i,t}$	Carbon dioxide emissions from fossil fuel combustion in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$CO2\_ff_{wp,i,t}$	Carbon dioxide emissions from fossil fuel combustion in the project scenario for sample unit *i* in year *t*; t CO_2e/unit area
i	Sample unit

Equation 36

$$\overline{\Delta C_{TREE,t}} = \overline{\Delta C_{TREE,wp,t}} - \overline{\Delta C_{TREE,bsl,t}}$$

Where:

$\overline{\Delta C_{TREE,t}}$	Areal average carbon dioxide emission reductions from tree biomass in year *t*; t CO_2-e/unit area
$\overline{\Delta C_{TREE,wp,t}}$	Areal average baseline carbon stock change in tree biomass in year *t*; t CO_2-e/unit area
$\overline{\Delta C_{TREE,bsl,t}}$	Areal average project scenario carbon stock change tree biomass in year *t*; t CO_2-e/unit area

Equation 37

$$\overline{\Delta C_{SHRUB,t}} = \overline{\Delta C_{SHRUB,wp,t}} - \overline{\Delta C_{SHRUB,bsl,t}}$$

Where:

$\overline{\Delta C_{SHRUB,t}}$	Areal average carbon dioxide emission reductions from tree biomass in year *t*; t CO_2-e/unit area
$\overline{\Delta C_{SHRUB,wp,t}}$	Areal average baseline carbon stock change in tree biomass in year *t*; t CO_2-e/unit area
$\overline{\Delta C_{SHRUB,bsl,t}}$	Areal average project scenario carbon stock change tree biomass in year *t*; t CO_2-e/unit area

8.5.2 Methane emission reductions ($\overline{\Delta CH4_t}$)

See parameter tables in Section 9.2 for derivation of $\overline{\Delta}_{\bullet,t}$ and $\overline{\bullet}_t$

Methane emission reductions are quantified as:

Equation 38

$$\overline{\Delta CH4_t} = \overline{\Delta CH4\_soil_t} + \overline{\Delta CH4\_ent_t} + \overline{\Delta CH4\_md_t} + \overline{\Delta CH4\_bb_t}$$

Where:

$\overline{\Delta CH4_t}$	Areal average methane emission reductions in year t; t CO_2e/unit area
$\overline{\Delta CH4\_soil_t}$	Areal average methane emission reductions from soil organic carbon pool in year t; t CO_2e/unit area
$\overline{\Delta CH4\_ent_t}$	Areal average methane emission reductions from livestock enteric fermentation in year t; t CO_2e/unit area
$\overline{\Delta CH4\_md_t}$	Areal average methane emission reductions from manure deposition in year t; t CO_2e/unit area
$\overline{\Delta CH4\_bb_t}$	Areal average methane emission reductions from biomass burning in year t; t CO_2e/unit area

Methane emission reductions from the soil organic carbon pool are quantified as:

Equation 39

$$\Delta CH4\_soil_{i,t} = \left(CH4\_soil_{bsl,i,t} - CH4\_soil_{wp,i,t}\right)$$

Where:

$\Delta CH4\_soil_{i,t}$	Methane emission reductions from soil organic carbon pool for sample unit *i* in year t; t CO_2e/unit area
$CH4\_soil_{bsl,i,t}$	Methane emissions from soil organic carbon pool in the baseline scenario for sample unit *i* in year t; t CO_2e/unit area
$CH4\_soil_{wp,i,t}$	Methane emissions from soil organic carbon pool in the project scenario for sample unit *i* in year t; t CO_2e/unit area
i	Sample unit

Methane emission reductions from livestock enteric fermentation are quantified as:

Equation 40

$$\Delta CH4\_ent_{i,t} = CH4\_ent_{bsl,i,t} - CH4\_ent_{wp,i,t}$$

Where:

$\Delta CH4\_ent_{i,t}$	Methane emission reductions from livestock enteric fermentation for sample unit *i* in year *t*; t CO_2e/unit area
$CH4\_ent_{bsl,i,t}$	Methane emissions from livestock enteric fermentation in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$CH4\_ent_{wp,i,t}$	Methane emissions from livestock enteric fermentation in the project scenario for sample unit *i* in year *t*; t CO_2e/unit area
i	Sample unit

Methane emission reductions from manure deposition are quantified as:

Equation 41

$$\Delta CH4\_md_{i,t} = CH4\_md_{bsl,i,t} - CH4\_md_{wp,i,t}$$

Where:

$\Delta CH4\_md_{i,t}$	Methane emission reductions from manure deposition for sample unit *i* in year *t*; t CO_2e/unit area
$CH4\_md_{bsl,i,t}$	Methane emissions from manure deposition in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$CH4\_md_{wp,i,t}$	Methane emissions from manure deposition in the project scenario for sample unit *i* in year *t*; t CO_2e/unit area
i	Sample unit

Methane emission reductions from biomass burning are quantified as:

Equation 42

$$\Delta CH4\_bb_{i,t} = CH4\_bb_{bsl,i,t} - CH4\_bb_{wp,i,t}$$

Where:

$\Delta CH4\_bb_{i,t}$	Methane emission reductions from biomass burning for sample unit *i* in year *t*; t CO_2e/unit area
$CH4\_bb_{bsl,i,t}$	Methane emissions from biomass burning in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$CH4\_bb_{wp,i,t}$	Methane emissions from biomass burning in the project scenario for sample unit *i* in year *t;* t CO_2e/unit area
i	Sample unit

8.5.3 Nitrous oxide emission reductions ($\overline{\Delta N2O_t}$)

See parameter tables in Section 9.2 for derivation of $\overline{\Delta}_{\bullet,t}$ and $\overline{\bullet}_t$

Nitrous oxide emission reductions are quantified as:

Equation 43

$$\overline{\Delta N2O_t} = \overline{\Delta N2O\_soil_t} + \overline{\Delta N2O\_bb_t}$$

Where:

$\overline{\Delta N2O_t}$	Areal average nitrous oxide emission reductions in year *t*; t CO_2e/unit area
$\overline{\Delta N2O\_soil_t}$	Areal average nitrous oxide emission reductions from nitrification/denitrification in year *t*; t CO_2e/unit area
$\overline{\Delta N2O\_bb_t}$	Areal average nitrous oxide emission reductions from biomass burning in year *t*; t CO_2e/unit area

Nitrous oxide emission reductions from nitrification/denitrification are quantified as:

Equation 44

$$\Delta N2O\_soil_{i,t} = N2O\_soil_{bsl,i,t} - N2O\_soil_{wp,i,t}$$

Where:

$\Delta N2O\_soil_{i,t}$	Nitrous oxide emission reductions from nitrification/denitrification for sample unit *i* in year *t*; t CO_2e/unit area
$N2O\_soil_{bsl,i,t}$	Nitrous oxide emissions from nitrogen inputs to soils in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$N2O\_soil_{wp,i,t}$	Nitrous oxide emissions from nitrogen inputs to soils in the project scenario for sample unit *i* in year *t*; t CO_2e/unit area
i	Sample unit

Nitrous oxide emission reductions from biomass burning are quantified as:

Equation 45

$$\Delta N2O\_bb_{i,t} = N2O\_bb_{bsl,i,t} - N2O\_bb_{wp,i,t}$$

Where:

$\Delta N2O\_bb_{i,t}$	Nitrous oxide emission reductions from biomass burning for sample unit *i* in year *t*; t CO_2e/unit area

$N2O\_bb_{bsl,i,t}$	Nitrous oxide emissions from biomass burning in the baseline scenario for sample unit *i* in year *t*; t CO_2e/unit area
$N2O\_bb_{wp,i,t}$	Nitrous oxide emissions from biomass burning in the project scenario for sample unit *i* in year *t*; t CO_2e/unit area
i	Sample unit

8.6 Uncertainty

Key sources of uncertainty accounted for are sample error and, where models are applied (Quantification Approach 1), measurement error of model inputs and model prediction error. Uncertainty in area estimation is addressed via complete (and accurate) GIS boundaries of the project area, applying QA/QC procedures specified in the parameter table for A_i.

Estimators of uncertainty provided below assume simple random sampling with replacement with a two-stage sample design, represented by sample points (e.g., points where soil cores are taken) within sample units (e.g., sample fields). Other unbiased sample designs (e.g., stratified samples, variable probability samples, further multi-stage samples) may also be employed, and estimators of variance reconfigured to permit un-biased estimation.

Total uncertainty deduction, UNC_t, is quantified as:

Equation 46

$$UNC_t = MIN\left(100\%, MAX\left(0, \frac{T\sqrt{\sum_{\bullet} s^2_{\Delta\bullet,t}}}{\overline{\Delta CO2_t} + \overline{\Delta CH4_t} + \overline{\Delta N2O_t}} - 15\%\right)\right)$$

Where:

UNC_t	Uncertainty deduction in year *t* (expressed as the extent to which the half width of the 95% confidence interval, as a percentage of the mean, exceeds the threshold of 15%); unitless number between 0 and 1
$\sum_{\bullet}$	Sum over pools and gases CO2_soil, CTREE, CSHRUB,[24] CH4_SOC, CH4_ent, CH4_md, and N2O_soil, where Quantification Approaches 1 or 2 were employed.
$s^2_{\Delta\bullet,t}$	Variance of the estimate of $\overline{\Delta\bullet}\,t$. ($\overline{\Delta\bullet}\,t$ = mean emission reductions from gas and pool • at time *t*) (see); (t CO2e/unit area)^2
$\overline{\Delta CO2_t}$	Areal average carbon dioxide emission reductions in year *t*; t CO_2e/unit area

[24] Uncertainty related to quantification of changes in woody biomass are quantified outside of this methodology according to the tool specified in Table 2.

$\overline{\Delta CH4_t}$	Areal average methane emission reductions in year t; t CO_2e/unit area
$\overline{\Delta N2O_t}$	Areal average nitrous oxide emission reductions in year t; t CO_2e/unit area
T	Critical value of a student's t-distribution for significance level $\alpha = 0.05$ (i.e., a $1 - \alpha = 95\%$ confidence interval) and the degrees of freedom df appropriate for the design used (e.g., $\mathrm{df} = n - 1$ for a simple random sample of n sample units)
15%	Threshold beyond which there is an uncertainty deduction
•	Gas or pool

Where Quantification Approach 3 is employed, the standard error for that source is set equal to zero. Uncertainty calculations for individual gases and pools differ depending on the quantification approach used.

8.6.1 Quantification Approach 1

Model prediction error

Model prediction error is quantified from paired modeled and direct-re-measured sites in an experimental sampling regime subject to control and treatment scenarios as:

Equation 47

$$s_{\mathrm{struct},\Delta\bullet,t} = s_{\bullet}\sqrt{2(1-\rho_{\bullet})}$$

Where:

$s_{struct,\Delta\bullet,t}$	(Approximate) standard error in $\Delta\bullet$ ($\Delta\bullet$ = emission reductions in gas and pool •) due to model prediction error at time t; t CO_2e/unit area
$s_{\bullet}$	Standard deviation of the residuals ($\bullet_{measured}$ - $\bullet_{modeled}$). • = modeled or measured emission or stock change in gas and pool • over a fixed interval); t CO_2e/unit area
$\rho_{\bullet}$	Correlation coefficient of (i) model errors in the project scenario and (ii) model errors in the baseline scenario in gas and pool • over a fixed interval; dimensionless
•	Gas or pool

If a performance benchmark is used for the baseline or if the SOC stock is directly remeasured, then $s_{\mathrm{struct},\Delta\bullet,t} = s_{\bullet}$.

It is assumed that the standard deviation $s_{\bullet}$ of the residuals ($\bullet_{measured}$ - $\bullet_{modeled}$) is the same in the control and treatment scenarios. Data for quantifying model prediction error may be sourced from studies conducted external to the project area, and should be from the same datasets used to validate the model (as detailed in VMD0053 “Model Calibration and Validation Guidance for the Methodology for Improved Agricultural Land Management”).

If the amount of data for quantifying model prediction error varies significantly among crops, soil texture, and climate zones (see VMD0053 “Model Calibration and Validation Guidance for the Methodology for Improved Agricultural Land Management”), then a model prediction error could be estimated for groups of similar sites (e.g., based on a stratification applied to the fields in the project and to the sites in the validation data, or based on a Gaussian Process fit to the validation data with biophysical variables, management practices, and/or other variables as predictors). That way, a model prediction error can be assigned to each sample point i: $s_{\text{struct},\Delta\bullet,i,t}$. Then $s^2_{\text{struct},\Delta\bullet,t}$ is the model error variance for the population, estimated from the $s^2_{\text{struct},\Delta\bullet,i,t}$ using the sample design used. For example, for a simple random sample or for the self-weighting two-stage design described below, $s^2_{\text{struct},\Delta\bullet,t}$ is an average of the $s^2_{\text{struct},\Delta\bullet,i,t}$ across i [see Cochran (1977, eq. 13.39)].

Model input measurement error

Measurement errors of model inputs are automatically captured by the estimate of sample error (discussed below), provided that the measurement errors are uncorrelated across sample points [see, e.g., Cochran (1977, p. 382); de Gruijter et al. (2006, p. 82); Som (1995, p. 438)]. QA/QC procedures for model inputs ensure that model inputs are sufficiently accurate and that measurement errors are uncorrelated with each other (see model input requirements in Tables 8.1 and 8.2).

Sample and measurement error

Here, we give an example of a two-stage design with first-stage units chosen with probability proportional to their acreage (with replacement) and with second-stage units chosen with simple random sampling (with replacement). For example, the first-stage units could be fields that are tiled with a fine grid; the second-stage units are tiles within the grid, and the tiles all have the same area. This design could be modified in many ways, for example by assigning fields to strata, or by eliminating fields as a sampling unit and instead creating strata of tiles.

In the first stage, n out of N fields are selected with probability proportional to their acreage with replacement. (If a field is chosen multiple times, then tiles are independently selected from that field multiple times.) Subsequent calculations are simplified by making the probability of selecting field i equal to its area A_i divided by the total area A_0 of all fields, i.e., probability proportional to size (PPS) sampling:

Equation 48

$$\pi_i = \frac{A_i}{A_0}$$

Within each selected field i, m_i tiles are chosen with simple random sampling with replacement. The estimator of the emissions reduction averaged across all tiles is the simple (unweighted) average across all sampled fields and sampled tiles [Som (1995), eq. 16.18; Cochran (1977), eq. 11.39]:

Equation 49

$$\overline{\Delta \bullet}_t = \frac{1}{n}\sum_{i=1}^{n}\overline{\Delta \bullet_{\iota,t}} = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{m_i}\sum_{k=1}^{m_i}\Delta \bullet_{i,k,t}$$

Where,

$\overline{\Delta \bullet}_t$	Areal average unbiased estimator of emissions reduction for gas or pool • in year *t*; t CO_2e/unit area
$\overline{\Delta \bullet_{\iota,t}}$	Areal average emissions reduction of gas or pool • in year *t* in field *i*, computed as the average across the sample points in field *i* (areal average), $(1/m_i)\sum_{k=1}^{m_i}\Delta \bullet_{i,k,t}$; t CO_2e/unit area
$\Delta \bullet_{i,k,t}$	Estimated emissions reduction of gas or pool • in year *t* in field *i,* tile *k* (summed across the whole reporting period for field *i*, tile *k in year t*)*;* t CO_2e/unit area
m_i	Number of secondary sampling units (here, tiles) selected to be sampled within field *i*
n	Number of primary sampling units (here, fields) selected to be sampled
i	Primary sampling unit (here, field)
k	Secondary sampling unit (here, tile) within a primary sampling unit (here, field)

Ignoring model errors, an unbiased estimator of the variance of $\overline{\Delta \bullet_t}$, is, from [Som (1995), eq. 16.19; Cochran (1977), eq. 11.40],

Equation 50

$$s^2_{\text{sample \& meas.},\Delta\bullet,t} = \frac{\sum_{i=1}^{n}\left(\overline{\Delta \bullet_{i,t}} - \overline{\Delta \bullet_t}\right)^2}{n(n-1)}$$

Where

$s^2_{\text{sample \& meas.},\Delta\bullet,t}$	(Approximate) standard error in *Δ• (Δ•* = emission reductions in gas and pool •*)* due to sample error at time *t*; t CO_2e/unit area
$\overline{\Delta \bullet_{\iota,t}}$	Area average emissions reduction of gas or pool • in year *t* in field *i*, computed as the average across the sample points in field *i* (areal average), $(1/m_i)\sum_{k=1}^{m_i}\Delta \bullet_{i,k,t}$; t CO_2e/unit area
$\overline{\Delta \bullet_t}$,	Areal average unbiased estimator of variance for gas or pool • in year *t*; t CO_2e/unit area

n	Number of primary sampling units (here, fields) selected to be sampled

To fix the amount of work in each field, set m_i equal to constant m across all fields. Then the design becomes "self-weighting," and Equation 49 simplifies to an average across all measurements, $\overline{\Delta \bullet}_t = \frac{1}{n\,m}\sum_{i=1}^{n}\sum_{k=1}^{m}\Delta \bullet_{i,k,t}$ where $\Delta \bullet_{i,k,t}$ is the estimated emissions reduction of gas/pool • at point *k* in field *i*.

Combined sample and model error

To incorporate model errors, we assume that they are uncorrelated with the measurements in the sample, and we assume that model errors are independent across samples. Then by [Cochran (1977), eq. 13.39; Som (1995), eq. 25.10], the variance of $\overline{\Delta \bullet}_t$ incorporating sample uncertainty, lab measurement uncertainty, and model prediction uncertainty is:

Equation 51

$$s^2_{\Delta\bullet,t} = s^2_{\text{sample \& meas.},\Delta\bullet,t} + \frac{s^{\,2}_{\text{struct},\Delta\bullet,t}}{n \times m}$$

Where

$s^2_{\Delta\bullet,t}$	Variance of the estimate of $\overline{\Delta \bullet}\,t$. ($\overline{\Delta \bullet}\,t$ = mean emission reductions from gas and pool • at time *t*); (t CO_2e/unit area)[2]
$s^2_{\text{sample \& meas.},\Delta\bullet,t}$	(Approximate) standard error in $\Delta\bullet$ *(*$\Delta\bullet$ = emission reductions in gas and pool •*)* due to sample error at time *t*; t CO_2e/unit area
$s^{\,2}_{\text{struct},\Delta\bullet,t}$	(Approximate) standard error in $\Delta\bullet$ *(*$\Delta\bullet$ = emission reductions in gas and pool •*)* due to model prediction error at time *t*; t CO_2e/unit area
m	Number of secondary sampling units (here, tiles) selected to be sampled within primary sampling units (here, fields)
n	Number of primary sampling units (here, fields) selected to be sampled

When stock change in soil organic carbon is periodically directly re-measured in the project scenario, model (input and prediction error) uncertainty is only accounted for in the baseline scenario.

8.6.2 Quantification Approach 2

For Quantification Approach 2, where the baseline is represented by a performance benchmark (i.e., a fixed value with no uncertainty), uncertainty is restricted to sample error around stock change in the project scenario.

The standard error of the soil carbon stock change is calculated as:

Equation 52

$$s^2_{\Delta\bullet,t} = \frac{1}{n} * \left(s^2_{\bullet,wp,t} + s^2_{\bullet,wp,t-1} - 2 * Cov\left(\bullet_{wp,t}, \quad \bullet_{wp,t-1}\right)\right)$$

Where:

$s^2_{\Delta\bullet,t}$	Variance of the estimate of $\overline{\Delta \bullet} t$. ($\overline{\Delta \bullet} t$ = mean emission reductions from gas and pool • at time *t*); (t CO_2e/unit area)^2
$s^2_{\bullet,wp,t}$	Variance of $\bullet_{wp,t}$ (• = emissions from gas or pool •) in the project scenario at time *t*; (t CO2e/unit area)^2
$s^2_{\bullet,wp,t-1}$	Variance of $\bullet_{wp,t}$ (• = emissions from gas or pool •) in the project scenario at time *t-1*; (t CO2e/unit area)^2
$Cov(\bullet_{wp,t}, \bullet_{wp,t-1})$	Covariance of $\bullet_{wp,t}$ and $\bullet_{wp,t-1}$; (t CO2e/unit area)^2
n	Number of primary sampling units (here, fields) selected to be sampled
•	Gas or pool

8.7 Calculation of Verified Carbon Units

In order to calculate the number of Verified Carbon Units (VCU) that may be issued, the project proponent must consider the number of buffer credits which must be deposited in the AFOLU pooled buffer account. The number of buffer credits which must be deposited in the AFOLU pooled buffer account is based on the net change in carbon stocks.

The number of VCU that may be issued in year *t* is calculated as:

Equation 53

$$VCU_t = ER_t - Buffer_t$$

VCU_t	Number of VCU in year *t*; t CO_2e
ER_t	Estimated net GHG emissions reductions and removals in year *t*; t CO_2e
$Buffer_t$	Number of buffer credits to be contributed to the AFOLU pooled buffer account in year *t*; t CO_2e

9 MONITORING

Where discretion exists in the selection of a value for a parameter, the principle of conservativeness must be applied (as described in Section 2.2.1 of the *VCS Standard, v4.0*).

Box 1

Sources of information for all un-defined activity/management related model input variables (see Tables 4 and 7) and parameters $FFC_{bsl,j,i,t}$, $P_{bsl,l,i,t}$, $Days_{bsl,l,i,t}$, $M_{bsl,SF,i,t}$, $M_{bsl,OF,i,t}$, and $MB_{g,bsl,i,t}$, , relevant to the baseline, will follow requirements detailed below.

All *qualitative* information on agricultural management practices will be determined via consultation with, and substantiated with a signed attestation from, the farmer or landowner of the sample field during that period.

The source of *quantitative* information on agricultural management practices, and any additional quantitative inputs where required by the model selected (Quantification Approach 1 and 2), or by the default (Quantification Approach 3), must be chosen with priority from higher to lower preference, as available, as follows, applying the principle of conservatism in all cases:

1. Historical management records supported by one or more forms of documented evidence pertaining to the selected sample field and period t = -1 to t = -5 (e.g., management logs, receipts or invoices, farm equipment specifications, logs or files containing machine and/or sensor data), or remote sensing (e.g., satellite imagery, manned aerial vehicle footage, drone imagery) , where requisite information on agricultural management practices can be reliably determined with these methods (e.g., tillage status, crop type, irrigation).
2. Historical management plans supported by one or more forms of documented evidence pertaining to the selected sample field and period t = -1 to t = -5 (e.g., management plan, recommendations in writing solicited by the farmer or landowner from an agronomist). Where more than one value is documented in historical management plans (e.g., where a range of application rates are prescribed in written recommendations), the principle of conservatism will be applied, selecting the value that results in the lowest expected emissions (or highest rate of stock change) in the baseline scenario.
3. Determined via consultation with, and substantiated with a signed attestation from the farmer or landowner of the sample field during that period - so long as the attested value does not deviate significantly from other evidence-supported values for similar fields (e.g., fertilizer data from adjacent fields with the same crop, adjacent years of the same field, government data of application rates in that area, or statement from a local extension agent regarding local application rates). The determination of the sufficiency of data is subject to the discretion of the validator. In circumstances where this requirement cannot be met, option d must be followed.
4. Regional (sub-national) average values derived from agricultural census data or other sources from within the 20-year period preceding the project start date or the 10 most recent iterations of the dataset, whichever is more recent, referencing the relevant crop or ownership class where estimates have been disaggregated by those attributes, and substantiated with a signed attestation from the farmer or landowner of the sample field during that period. Examples include the US Department of Agriculture (USDA) National Agricultural Statistics Service Quick Stats database and USDA Agricultural Resource Management Survey.

9.1 Data and Parameters Available at Validation

Data / Parameter	AR
Data unit	Percent
Description	Weighted average adoption rate
Equations	Equation 1
Source of data	Calculated for the project across the group or all activity instances
Value applied	Must be less than or equal to 20%
Justification of choice of data or description of measurement methods and procedures applied	See Section 7
Purpose of Data	Common practice assessment
Comments	None

Data / Parameter	$Area_{an}$
Data unit	Hectares or acres
Description	Area of proposed project-level adoption of each activity
Equations	Equation 1
Source of data	Farm records and project activity commitments
Value applied	The proposed project-level adoption of $Activity_{an}$
Justification of choice of data or description of measurement methods and procedures applied	See Section 7
Purpose of Data	Common practice assessment
Comments	None

Data / Parameter	EA_{an}
Data unit	Percent
Description	Adoption rate of the n largest most common proposed project activity in the region
Equations	Equation 1
Source of data	Publicly available information contained in agricultural census or other government (e.g., survey) data, peer-reviewed scientific literature, independent research data, or reports/assessments compiled by industry associations. If all of the above sources are unavailable, signed and date attestation statement from a qualified independent local expert.
Value applied	Conditional on data source
Justification of choice of data or description of measurement methods and procedures applied	See source of data above and Section 7
Purpose of Data	Common practice assessment
Comments	None

Data / Parameter	A_0
Data unit	Unit area
Description	Project area
Equations	Equation 48
Source of data	Measured in project area
Value applied	The project area is measured prior to validation
Justification of choice of data or description of measurement methods and procedures applied	Delineation of the project area may use a combination of GIS coverages, ground survey data, remote imagery (satellite or aerial photographs), or other appropriate data. Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points.

Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$EF_{CO2,j}$
Data unit	t CO_2e/liter
Description	Emission factor for the type of fossil fuel *j* (gasoline or diesel) combusted
Equations	Equation 4
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2 Chapter 3 Table 3.3.1
Value applied	For gasoline EF_{CO2}=0.002810 t CO_2e per liter. For diesel EF_{CO2}=0.002886 t CO_2e per liter
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	Assumes 4-stroke gasoline engine for gasoline combustion and default values for energy content of 47.1 GJ/t and 45.66 GJ/t for gasoline and diesel respectively (IEA. 2005. Energy Statistics Manual).

Data / Parameter	$FFC_{bsl,j,i,t}$
Data unit	Liters
Description	Consumption of fossil fuel type *j* (gasoline or diesel) for sample unit *i* in year *t*
Equations	Equation 4
Source of data	See Box 1
Value applied	See Box 1
Justification of choice of data or description of	Fossil fuel consumption can be monitored, or the amount of fossil fuel combusted can be estimated using fuel efficiency (for

measurement methods and procedures applied	example l/100 km, l/t-km, l/hour) of the vehicle and the appropriate unit of use for the selected fuel efficiency (for example km driven if efficiency is given in l/100 km).
Purpose of Data	Calculation of baseline
Comments	Peer-reviewed published data may be used to determine fuel efficiency. For example, fuel efficiency factors may be obtained from the 2019 Refinement to IPCC 2006 Volume 2 Chapter 3

Data / Parameter	GWP_{CH4}
Data unit	t CO2e/t CH_4
Description	Global warming potential for CH_4
Equations	Equation , Equation , Equation 7, and Equation 9
Source of data	IPCC Fourth Assessment Report
Value applied	25
Justification of choice of data or description of measurement methods and procedures applied	See source of data above. Unless otherwise directed by the VCS Program, VCS Standard v4.0 requires that CH_4 must be converted using the 100-year global warming potential derived from the IPCC Fourth Assessment Report.
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$EF_{ent,l}$
Data unit	kg CH_4/(head * year)
Description	Enteric emission factor for livestock type *l*
Equations	Equation 6
Source of data	Peer-reviewed published data may be used. For example, suitable values may be selected from the 2019 Refinement to

	the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 Table 10.10 and Table 10.11
Value applied	The emission factor is selected based on livestock type
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$EF_{CH4,md,l}$
Data unit	g CH4/(kg volatile solids)
Description	Emission factor for methane emissions from manure deposition for livestock type *l*
Equations	Equation 7
Source of data	Peer-reviewed published data may be used. For example, suitable values may be selected from the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 Table 10.14 and Table 10.15
Value applied	The emission factor is determined based on livestock type. Excluding livestock types listed in Table 10.15 in Chapter 10 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4, a value of 0.6 is applied for all animals in both low and high productivity pasture, range, and paddock systems per Table 10.14 of the same chapter.
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$VS_{rate,l}$
Data unit	kg volatile solids/(1000 kg animal mass * day)
Description	Default volatile solids excretion rate for livestock type *l*
Equations	Equation 8
Source of data	Peer-reviewed published data may be used. For example, suitable values may be selected from the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 Table 10.13a
Value applied	The volatile solids excretion rate is determined based on livestock type. Where agricultural systems are differentiated into low and high productivity systems in Table 10.13a in Chapter 10 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4, the mean value is selected.
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	CF_c
Data unit	Proportion of pre-fire fuel biomass consumed
Description	Combustion factor for agricultural residue type *c*
Equations	Equation 9, Equation 27
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 2 Table 2.6
Value applied	The combustion factor is selected based on the agricultural residue type burned
Justification of choice of data or description of	See source of data above

measurement methods and procedures applied	
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$EF_{c,CH4}$
Data unit	g CH_4/kg dry matter burnt
Description	Methane emission factor for the burning of agricultural residue type *c*
Equations	Equation 9
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 2 Table 2.5
Value applied	The emission factor is selected based on the agricultural residue type burned
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	GWP_{N2O}
Data unit	t CO_2e / t N_2O
Description	Global warming potential for N_2O
Equations	Equation 13, Equation 17, Equation 18, Equation 19, Equation 22, Equation 25, and Equation 27
Source of data	IPCC Fourth Assessment Report
Value applied	298

Justification of choice of data or description of measurement methods and procedures applied	See source of data above. Unless otherwise directed by the VCS Program, VCS Standard v4.0 requires that N_2O must be converted using the 100-year global warming potential derived from the IPCC Fourth Assessment Report.
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$EF_{Ndirect}$
Data unit	t N2O-N/t N applied
Description	Emission factor for direct nitrous oxide emissions from N additions from synthetic fertilizers, organic amendments and crop residues
Equations	Equation 13, Equation 19
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.1
Value applied	A value of 0.004 is applied for flooded rice fields. A value of 0.01 is applied for all other fields.
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	Emission factor applicable to N additions from mineral fertilizers, organic amendments and crop residues, and N mineralized from mineral soil as result of loss of soil carbon

Data / Parameter	$Frac_{GASF}$
Data unit	Dimensionless
Description	Fraction of all synthetic N added to soils that volatilizes as NH_3 and NO_x
Equations	Equation 17

Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3
Value applied	0.11
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$Frac_{GASM}$
Data unit	Dimensionless
Description	Fraction of all organic N added to soils and N in manure and urine deposited on soils that volatilizes as NH_3 and NO_x
Equations	Equation 17, Equation 25
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3
Value applied	0.21
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	EF_{Nvolat}
Data unit	t N_2O-N /(t NH_3-N + NOx-N volatilized)
Description	Emission factor for nitrous oxide emissions from atmospheric deposition of N on soils and water surfaces
Equations	Equation 17, Equation 25

Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3
Value applied	0.01
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$Frac_{LEACH}$
Data unit	Dimensionless
Description	Fraction of N added (synthetic or organic) to soils and N in manure and urine deposited on soils that is lost through leaching and runoff, in regions where leaching and runoff occurs
Equations	Equation 18, Equation 26
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3
Value applied	For wet climates or in dry climate regions where irrigation (other than drip irrigation) is used, a value of 0.24 is applied. For dry climates, a value of zero is applied.
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	Wet climates occur in temperate and boreal zones where the ratio of annual precipitation : potential evapotranspiration > 1, and tropical zones where annual precipitation > 1000 mm. Dry climates occur in temperate and boreal zones where the ratio of annual precipitation : potential evapotranspiration < 1, and tropical zones where annual precipitation < 1000 mm.

Data / Parameter	EF_{Nleach}
Data unit	t N_2O-N / t N leached and runoff
Description	Emission factor for nitrous oxide emissions from leaching and runoff
Equations	Equation 18, Equation 26
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3
Value applied	0.011
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$EF_{N2O,md,l}$
Data unit	kg N_2O-N/kg N input
Description	Emission factor for nitrous oxide from manure and urine deposited on soils by livestock type *l*
Equations	Equation 22
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.1
Value applied	The emission factor for nitrous oxide from manure and urine deposited on soils is determined based on livestock type. For cattle, poultry, and pigs $EF_{N2O,md,l}$ = 0.004 kg N_2O-N/kg N input. For sheep and other animals $EF_{N2O,md,l}$=0.003 kg N_2O-N/kg N input.
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions

Comments	None

Data / Parameter	Nex_l
Data unit	kg N deposited/(t livestock mass * day)
Description	Nitrogen excretion of livestock type *l*
Equations	Equation 23
Source of data	Peer-reviewed published data may be used. For example, suitable values may be selected from the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 Table 10.19
Value applied	The nitrogen excretion rate is determined based on livestock type. Where agricultural systems are differentiated into low and high productivity systems in Table 10.19 in Chapter 10 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4, the mean value is selected.
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$MS_{bsl,l,i,t}$
Data unit	Fraction of N deposited
Description	Fraction of nitrogen excretion of livestock type *l* that is deposited on the project area
Equations	Equation 23
Source of data	Data may be sourced according to the guidance in Box 1
Value applied	The fraction of nitrogen deposited on the project area is determined based on the amount of time spent grazing on the project area during year *t* for each livestock type. In the absence

	of data available according to Box 1 (or to conservatively reduce the effort of project development), a value of 1 may be applied with no additional support. This would conservatively assume that the livestock deposited 100% of their excreted N on the project area for the entirety of year *t*.
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$N_{content,g}$
Data unit	t N/t dm
Description	Fraction of N in dry matter for N-fixing species *g*
Equations	Equation 20
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.2
Value applied	The fraction of N in dry matter is determined based on the N-fixing species type.
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$EF_{c,N2O}$
Data unit	g N_2O/kg dry matter burnt
Description	Nitrous oxide emission factor for the burning of agricultural residue type *c*

Equations	Equation 27
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 2 Table 2.5
Value applied	The emission factor is selected based on the agricultural residue type.
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$P_{bsl,l,i,t}$
Data unit	Head
Description	Population of grazing livestock in the baseline scenario of type *l* in sample unit *i* in year *t*
Equations	Equation , Equation 7, and Equation 23
Source of data	See Box 1
Value applied	See Box 1
Justification of choice of data or description of measurement methods and procedures applied	See Box 1
Purpose of Data	Calculation of baseline emissions
Comments	None

Data / Parameter	$Days_{bsl,l,i,t}$
Data unit	Days
Description	Average grazing days per head in the baseline scenario inside sample unit *i* for each livestock type *l* in year *t*

Equations	Equation , Equation 7, and Equation 23
Source of data	See Box 1
Value applied	See Box 1
Justification of choice of data or description of measurement methods and procedures applied	See Box 1
Purpose of Data	Calculation of baseline emissions
Comments	None

Data / Parameter	$MB_{bsl,c,i,t}$
Data unit	Kilograms
Description	Mass of agricultural residues of type *c* burned in the baseline scenario for sample unit *i* in year *t*
Equations	Equation 9, Equation 27
Source of data	Peer-reviewed published data may be used to estimate the aboveground biomass prior to burning.
Value applied	See source of data
Justification of choice of data or description of measurement methods and procedures applied	It is assumed that 100% of aboveground biomass is burned in both the baseline and with project cases.
Purpose of Data	Calculation of baseline emissions
Comments	Mass of residues burned is a function of the amount of aboveground biomass, the removal of aboveground biomass, and whether or not remaining residues are burned.

Data / Parameter	$M_{bsl,SF,i,t}$
Data unit	t fertilizer

Description	Mass of baseline N containing synthetic fertilizer applied for sample unit *i* in year *t*
Equations	Equation 14
Source of data	See Box 1
Value applied	See Box 1
Justification of choice of data or description of measurement methods and procedures applied	See Box 1
Purpose of Data	Calculation of baseline emissions
Comments	None

Data / Parameter	$NC_{bsl,SF,i,t}$
Data unit	t N/t fertilizer
Description	N content of baseline synthetic fertilizer applied
Equations	Equation 14
Source of data	See Box 1
Value applied	See Box 1
Justification of choice of data or description of measurement methods and procedures applied	N content is determined following fertilizer manufacturer's specifications
Purpose of Data	Calculation of baseline emissions
Comments	None

Data / Parameter	$M_{bsl,OF,i,t}$
Data unit	t fertilizer

Description	Mass of baseline N containing organic fertilizer applied for sample unit *i* in year *t*
Equations	Equation 15
Source of data	See Box 1
Value applied	See Box 1
Justification of choice of data or description of measurement methods and procedures applied	See Box 1
Purpose of Data	Calculation of baseline emissions
Comments	None

Data / Parameter	Nex_l
Data unit	kg N/head/year
Description	Average annual nitrogen excretion per head of livestock type *l*
Equations	Equation 23
Source of data	Peer-reviewed published data may be used. For example, suitable values may be derived from the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 Section 10.5, applying a Tier 2 approach to equation 10.30. Where agricultural systems are differentiated into low and high productivity systems in Table 10.19 in Chapter 10 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4, the mean value is selected. Typical animal mass values may be sourced from Annex 10A.1, Table 10A.5.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions

Comments	None

Data / Parameter	$NC_{bsl,OF,i,t}$
Data unit	t N/t fertilizer
Description	N content of baseline organic fertilizer applied
Equations	Equation 15
Source of data	Peer-reviewed published data may be used. For example, default manure N contents may be selected from Edmonds et al. (2003) cited in U.S. Environmental Protection Agency. (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. *EPA 430-R-11-005*. Washington, D.C. or other regionally appropriate sources such as the European Environment Agency.
Value applied	See source of data
Justification of choice of data or description of measurement methods and procedures applied	See source of data
Purpose of Data	Calculation of baseline emissions
Comments	None

Data / Parameter	$MB_{g,bsl,i,t}$
Data unit	t dm
Description	Annual dry matter, including aboveground and below ground, of N-fixing species *g* returned to soils for sample unit *i* at time *t*
Equations	Equation 20
Source of data	See Box 1
Value applied	See Box 1
Justification of choice of data or description of	See Box 1

measurement methods and procedures applied	
Purpose of Data	Calculation of baseline emissions
Comments	Mass of residues burned is a function of the amount of aboveground biomass, the removal of aboveground biomass, and whether or not remaining residues are burned.

Data / Parameter	$P_{bsl,p}$
Data unit	Productivity (e.g., kg) per hectare or acre
Description	Average productivity for product p during the historical baseline period
Equations	Equation 29, Equation 30
Source of data	See Box 1
Value applied	See Box 1
Justification of choice of data or description of measurement methods and procedures applied	See Box 1
Purpose of Data	Determination of baseline productivity for future market leakage analysis
Comments	None

Data / Parameter	$RP_{bsl,p}$
Data unit	Productivity (e.g., kg) per hectare or acre
Description	Average regional productivity for product p during the same years as the historical baseline period
Equations	Equation 30
Source of data	Secondary evidence sources of regional productivity (e.g., peer-reviewed science, industry associations, international databases, government databases)
Value applied	Conditional on data source

Justification of choice of data or description of measurement methods and procedures applied	See Box 1
Purpose of Data	Determination of baseline productivity ratio for future market leakage analysis
Comments	None

9.2 Data and Parameters Monitored

Data / Parameter:	AR
Data unit:	Percent
Description:	Weighted average adoption rate
Equations	Equation 1
Source of data:	Calculated for the project across the group or all activity instances
Description of measurement methods and procedures to be applied:	Not applicable
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	See Section 7
Purpose of data:	Common practice assessment
Calculation method:	See Section 7
Comments:	None

Data / Parameter:	$Area_{an}$
Data unit:	Unit area (hectares or acres)
Description:	Area of proposed project-level adoption of each activity

Equations	Equation 1
Source of data:	Farm records and project activity commitments
Description of measurement methods and procedures to be applied:	The area is estimated prior to verification
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Delineation of the sample unit area may use a combination of GIS coverages, ground survey data, remote imagery (satellite or aerial photographs), or other appropriate data. Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points.
Purpose of data:	Common practice assessment
Calculation method:	Not applicable (measured)
Comments:	None

Data / Parameter:	EA_{an}
Data unit:	Percent
Description:	Adoption rate of the n largest most common proposed project activity in the region
Equations	Equation 1
Source of data:	Publicly available information contained in agricultural census or other government (e.g., survey) data, peer-reviewed scientific literature, independent research data, or reports/assessments compiled by industry associations. If all of the above sources are unavailable, signed and date attestation statement from a qualified independent local expert.
Description of measurement methods and procedures to be applied:	Not applicable

Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	See Section 7
Purpose of data:	Common practice assessment
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	A_i
Data unit:	Unit area
Description:	Area of sample unit *i*
Equations	Equation , Equation , Equation 9, Equation 13, Equation 16, Equation 19, Equation 24, and Equation 48
Source of data:	Determined in project area
Description of measurement methods and procedures to be applied:	The sample unit area is measured prior to verification
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Delineation of the sample unit area may use a combination of GIS coverages, ground survey data, remote imagery (satellite or aerial photographs), or other appropriate data. Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points.
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	*i*
Data unit:	Dimensionless
Description:	Sample unit; defined area that is selected for measurement and monitoring, such as a field
Equations	Equation - Equation 27, Equation 33 - Equation 35, Equation 39 - Equation 42, Equation 44, Equation 45, Equation 48 - Equation 50
Source of data:	Determined in project area
Description of measurement methods and procedures to be applied:	The sample unit is determined prior to verification
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Delineation of the sample unit area may use a combination of GIS coverages, ground survey data, remote imagery (satellite or aerial photographs), or other appropriate data. Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points.
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	*j*
Data unit:	Dimensionless
Description:	Type of fossil fuel combusted
Equations	Equation , Equation 4
Source of data:	Determined in sample unit *i*
Description of measurement methods	See Box 1. Fossil fuel type is determined prior to verification.

and procedures to be applied:	
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See Box 1.
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	l
Data unit:	Dimensionless
Description:	Type of livestock
Equations	Equation , Equation 7, Equation 8, Equation 22, Equation 23, Equation 25, and Equation 26
Source of data:	Determined in sample unit *i*
Description of measurement methods and procedures to be applied:	See Box 1. Vehicle type is determined prior to verification.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See Box 1.
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	g

Data unit:	Dimensionless
Description:	Type of N-fixing species
Equations	Equation 20
Source of data:	Determined in sample unit *i*
Description of measurement methods and procedures to be applied:	See Box 1. N-fixing species type is determined prior to verification.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See Box 1.
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	c
Data unit:	Dimensionless
Description:	Type of agricultural residue
Equations	Equation 9, Equation 27
Source of data:	Determined in sample unit *i*
Description of measurement methods and procedures to be applied:	See Box 1. Agricultural residue type is determined prior to verification.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years

QA/QC procedures to be applied:	See Box 1.
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	•
Data unit:	Dimensionless
Description:	Gas or pool
Equations	Equation 46, Equation 47, Equation 49, and Equation 50
Source of data:	Determined in sample unit *i*
Description of measurement methods and procedures to be applied:	Not applicable
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Not applicable
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	*SF*
Data unit:	Dimensionless
Description:	Type of synthetic N fertilizer
Equations	Equation 14

Source of data:	Determined in sample unit *i*
Description of measurement methods and procedures to be applied:	See Box 1. Synthetic fertilizer type is determined prior to verification.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See Box 1.
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	*OF*
Data unit:	Dimensionless
Description:	Type of organic N fertilizer
Equations	Equation 15
Source of data:	Determined in sample unit *i*
Description of measurement methods and procedures to be applied:	See Box 1. Organic fertilizer type is determined prior to verification.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See Box 1.
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	Not applicable

Comments:	None

Data / Parameter:	$fSOC_{bsl,i,t}$
Data unit:	t CO_2e/unit area
Description:	Modeled soil organic carbon stocks pool in the baseline scenario for sample unit *i* at time *t*
Equations:	Equation
Source of data:	Modeled in the project area
Value applied:	
Description of measurement methods and procedures to be applied:	Modeled soil organic carbon stocks in the baseline scenario are determined according to the equation: $$SOC_{bsl,i,t} = f_{SOC}(Var\ A_{bsl,i,t}, Var\ B_{bsl,i,t}, \dots)$$ Where: $SOC\_soil_{bsl,i,t}$ = Modeled soil organic carbon stocks pool in the baseline scenario for sample unit *i* at time *t* (t CO_2e/unit area) f_{SOC} = Model predicting carbon dioxide emissions from the soil organic carbon pool (t CO_2e/unit area) $Var\ A_{bsl,i,t}$ = Value of model input variable A in the project scenario for sample unit *i* at time t (units unspecified) $Var\ B_{bsl,i,t}$ = Value of model input variable B in the project scenario for sample unit *i* at time t (units unspecified) See Box 1 for sources of data and description of measurement methods and procedures to be applied to obtain values for model input variables.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years

QA/QC procedures to be applied:	Standard QA/QC procedures for soil inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs available from published hand-books, such as those published by FAO and available on the FAO Soils Portal[25], or from the IPCC GPG LULUCF 2003 is recommended. Where emerging technologies (e.g., remote sensing) are used to determine SOC stocks at t = 0, an independent subject matter expert must issue a formal technical opinion explicitly validating the approach by confirming the integrity and accuracy of the SOC estimates derived from the emerging technology. The expert's assessment and conclusions must address at least the following: 1) Quality of the calibration dataset (e.g., spatial and temporal coverage, depth range, methodological lab measurement approach) 2) Representativeness and sufficiency of samples used for calibration, recalibration, and model validation, including how the sample size was determined 3) Performance of the technology (i.e., model coverage (%), R^2 (value), and model prediction error) 4) Appropriateness of covariates, data sources, and procedures used for data processing and feature engineering 5) Scientific rigor of technology selection (e.g., model architecture) 6) Appropriateness of variogram selection and fitting. 7) Coherence of error propagation and uncertainty quantification procedures.
Purpose of data:	Calculation of baseline emissions
Calculation method:	Not applicable
Comments:	The soil organic carbon stocks at time $t=0$ are directly measured at $t=0$ or (back-) modeled to $t=0$ from measurements collected within +/-5 years of $t=0$, or determined for t=0 via emerging technologies (e.g., remote sensing) with known uncertainty, and must be used in both the baseline and with- project scenario for the length of the project.

Data / Parameter:	$SOC_{bsl,i,t}$

[25] http://www.fao.org/soils-portal/soil-survey/sampling-and-laboratory-techniques/en/

Data unit:	t CO_2e/unit area
Description:	Areal-average soil organic carbon stocks in the baseline scenario for sample unit *i* in year *t*
Equations	Equation 33, Equation 34
Source of data:	Modeled or measured in the project area
Description of measurement methods and procedures to be applied:	See $ƒSOC_{bsl,i,t}$ above.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See $ƒSOC_{bsl,i,t}$ above.
Purpose of data:	Calculation of baseline emissions
Calculation method:	Not applicable
Comments:	The soil organic carbon stocks at time *t=0* are directly measured at *t=0* or (back-) modeled to *t =0* from measurements collected within +/-5 years of *t =0,* or determined for *t*=0 via emerging technologies (e.g., remote sensing) with known uncertainty, and must be used in both the baseline and with- project scenario for the length of the project. Soil organic carbon stocks in the baseline scenario for sample unit *i* must be reported every 5 years or less.

Data / Parameter:	$SOC_{bsl,i,t-1}$
Data unit:	t CO_2e/unit area
Description:	Areal-average soil organic carbon stocks in the baseline scenario for sample unit *i* in year *t-1*
Equations	Equation 33, Equation 34
Source of data:	Modeled or measured in the project area

Description of measurement methods and procedures to be applied:	See $fSOC_{bsl,i,t}$ above.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See $fSOC_{bsl,i,t}$ above.
Purpose of data:	Calculation of baseline emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	$SOC_{wp,i,t}$
Data unit:	t CO_2e/unit area
Description:	Areal-average soil organic carbon stocks in the project scenario for sample unit *i* in year *t*
Equations	Equation 33, Equation 34
Source of data:	Modeled or measured in the project area
Description of measurement methods and procedures to be applied:	Modeled soil organic carbon stocks in the project scenario are determined according to the equation: $$fSOC_{wp,i,t} = f_{SOC}(Var\ A_{wp,i,t}, Var\ B_{wp,i,t}, \ldots)$$ Where: $fSOC_{wp,i,t}$ = Modeled carbon dioxide emissions from soil organic carbon pool in the baseline scenario for sample unit *i* at time *t* (t CO_2e/unit area) f_{SOC} = Model predicting carbon dioxide emissions from the soil organic carbon pool (t CO_2e/unit area)

$Var\ A_{wp,i,t}$	= Value of model input variable A in the project scenario for sample unit *i* at time t (units unspecified)
$Var\ B_{wp,i,t}$	= Value of model input variable B in the project scenario for sample unit *i* at time t (units unspecified)

See Box 1 for sources of data and description of measurement methods and procedures to be applied to obtain values for model input variables.

Measured soil organic carbon must be determined from samples collected from sample plots located within each sample unit. All organic material (e.g., living plants, crop residue) must be cleared from the soil surface prior to soil sampling. Soil must be sampled to a minimum depth of 30 cm. Soil organic carbon stocks must be estimated from measurements of both soil organic carbon content and bulk density taken at the same time, at the project start and re-measured every 5 years of less.

Geographic locations of intended sampling points must be established prior to sampling. The location of both the intended sampling point and the actual sampling point must be recorded.

If multiple cores are composited to create a single sample, these cores must all be from the same depth and be fully homogenized prior to subsampling.

Soils must be shipped within 5 days of collection and should be kept cool until shipping.

Acknowledging the wide range of valid monitoring approaches, and that relative efficiency and robustness are circumstance-specific, sampling, measurement and estimation procedures for measuring are not specified in the methodology and may be selected by project proponents based on capacity and appropriateness. Stratification may be employed to improve precision but is not required. Estimates generated must:

- Be demonstrated to be unbiased and derived from representative sampling
- Accuracy of measurements and procedures is ensured through employment of quality assurance/quality control

	(QA/QC) procedures (to be determined by the project proponent and outlined in the monitoring plan) Soil sampling should follow established best practices, such as those found in: Cline, M.G. 1944. Principles of soil sampling. Soil Science. 58: 275 – 288. Petersen, R.G., and Calvin, L.D. Sampling. In A. Klute, editor, 1986. Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods. SSSA Book Ser. 5.1. SSSA, ASA, Madison, WI. Determination of percent soil organic carbon should follow established laboratory procedures, such as those found in: Nelson, D.W., and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. p. 539–580. In A.L. Page et al. (ed.) Methods of soil Analysis. Part 2. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI. Schumacher, B. A. Methods for the determination of total organic carbon (TOC) in soils and sediments. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-02/069 (NTIS PB2003-100822), 2002, or other regionally appropriate sources such as the European Environment Agency. Standardization of soil measurement methods is a globally recognized need (for example: ISRIC World Soil Information Service (WoSIS)- see Ribeiro et al. (2018)). Measurement procedures for soil organic carbon and bulk density should be thoroughly described, including all sample handling, preparation for analysis, and analysis techniques. Ribeiro, E., N. H. Batjes and A. van Oostrum. 2018. World Soil Information Service (WoSIS) - Towards the standardization and harmonization of world soil data. ISRIC Report 2018/01, 2018, Wageningen, Netherlands
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Standard QA/QC procedures for soil inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs available from published hand-books,

	such as those published by FAO and available on the FAO Soils Portal[26] or from the IPCC GPG LULUCF 2003 is recommended. Where emerging technologies (e.g., remote sensing) are used to determine SOC stocks at *t* = 0, an independent subject matter expert must issue a formal technical opinion explicitly validating the approach by confirming the integrity and accuracy of the SOC estimates derived from the emerging technology. The expert's assessment and conclusions must address at least the following: 1) Quality of the calibration dataset (e.g., spatial and temporal coverage, depth range, methodological lab measurement approach) 2) Representativeness and sufficiency of samples used for calibration, recalibration, and model validation, including how the sample size was determined 3) Performance of the technology (i.e., model coverage (%), R^2 (value), and model prediction error) 4) Appropriateness of covariates, data sources, and procedures used for data processing and feature engineering 5) Scientific rigor of technology selection (e.g., model architecture) 6) Appropriateness of variogram selection and fitting 7) Coherence of error propagation and uncertainty quantification procedures
Purpose of data:	Calculation of project emissions
Calculation method:	Not applicable
Comments:	The soil organic carbon stocks at time *t=0* are directly measured at *t=0* or (back-) modeled to *t =0* from measurements collected within +/-5 years of *t=0,* or determined for *t*=0 via emerging technologies (e.g., remote sensing) with known uncertainty, and must be used in both the baseline and with- project scenario for the length of the project. Soil organic carbon stocks in the project scenario for sample unit *i* must be reported every 5 years or less. Where re-measurement of soil organic carbon stocks indicates lower stocks than previously estimated by modeling, procedures in the most

[26] http://www.fao.org/soils-portal/soil-survey/sampling-and-laboratory-techniques/en/

	current version of the VCS Registration and Issuance Process for loss or reversal events are followed, as appropriate.

Data / Parameter:	$SOC_{wp,i,t-1}$
Data unit:	t CO_2e/unit area
Description:	Areal-average soil organic carbon stocks in the project scenario for sample unit *i* in year *t-1*
Equations	Equation 33, Equation 34
Source of data:	Modeled or measured in the project area
Description of measurement methods and procedures to be applied:	See $SOC_{wp,i,t}$ above.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See $SOC_{wp,i,t}$ above.
Purpose of data:	Calculation of project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	$fCH4soil_{bsl,i,t}$
Data unit:	t CH4/unit area
Description:	Modeled methane emissions from the soil organic carbon pool in the baseline scenario for sample unit *i* at time *t*
Equations:	Equation 4
Source of data:	Modeled in the project area
Value applied:	

Description of measurement methods and procedures to be applied:	Modeled soil organic carbon stocks in the baseline scenario are determined according to the equation: $$fCH4soil_{bsl,i,t} = f_{CH4soil}(Var\ A_{bsl,i,t}, Var\ B_{bsl,i,t}, \ldots)$$ Where: $fCH4soil_{bsl,i,t}$ = Modeled methane emissions from the soil organic carbon pool in the baseline scenario for sample unit *i* at time *t* (t CH_4/unit area) $f_{CH4soil}$ = Model predicting methane emissions from the soil organic carbon pool $Var\ A_{bsl,i,t}$ = Value of model input variable A in the project scenario for sample unit *i* at time *t* (units unspecified) $Var\ B_{bsl,i,t}$ = Value of model input variable B in the project scenario for sample unit *i* at time *t* (units unspecified) See Box 1 for sources of data and description of measurement methods and procedures to be applied to obtain values for model input variables.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Standard QA/QC procedures for soil inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs available from published hand-books, such as those published by FAO and available on the FAO Soils Portal[27], or from the IPCC GPG LULUCF 2003 is recommended.
Purpose of data:	Calculation of baseline emissions
Calculation method:	Not applicable
Comments:	The soil organic carbon stocks at time *t=0* are directly measured at *t=0* or (back-) modeled to *t =0* from measurements collected within +/-5 years of *t =0,* or determined for *t*=0 via emerging technologies (e.g., remote

[27] http://www.fao.org/soils-portal/soil-survey/sampling-and-laboratory-techniques/en/

	sensing) with known uncertainty, and must be used in both the baseline and with- project scenario for the length of the project.

Data / Parameter:	$fN2Osoil_{bsl,i,t}$
Data unit:	t N2O/unit area
Description:	Modeled nitrous oxide emissions from soil in the baseline scenario for sample unit *i* at time *t*
Equations:	Equation 10
Source of data:	Modeled in the project area
Value applied:	
Description of measurement methods and procedures to be applied:	Modeled nitrous oxide emissions from soil in the baseline scenario are determined according to the equation: $$fN2Osoil_{bsl,i,t} = f_{N2Osoil}(Var\ A_{bsl,i,t}, Var\ B_{bsl,i,t}, \ldots)$$ Where: $fN2Osoil_{bsl,i,t}$ = Modeled nitrous oxide emissions from soil in the baseline scenario for sample unit *i* at time *t* (t CH_4/unit area) $f_{N2Osoil}$ = Model predicting methane emissions from the soil organic carbon pool $Var\ A_{bsl,i,t}$ = Value of model input variable A in the project scenario for sample unit *i* at time *t* (units unspecified) $Var\ B_{bsl,i,t}$ = Value of model input variable B in the project scenario for sample unit *i* at time *t* (units unspecified) See Box 1 for sources of data and description of measurement methods and procedures to be applied to obtain values for model input variables.
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years

QA/QC procedures to be applied:	Standard QA/QC procedures for soil inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs available from published hand-books, such as those published by FAO and available on the FAO Soils Portal[28], or from the IPCC GPG LULUCF 2003 is recommended.
Purpose of data:	Calculation of baseline emissions
Calculation method:	Not applicable
Comments:	The soil organic carbon stocks at time *t=0* are directly measured at *t=0* or (back-) modeled to *t =0* from measurements collected within +/-5 years of *t =0,* or determined for *t*=0 via emerging technologies (e.g., remote sensing) with known uncertainty, and must be used in both the baseline and with- project scenario for the length of the project.

Data / Parameter:	$\Delta SOC_{bsl,i,t}$
Data unit:	t CO_2e/unit area
Description:	Estimated temporal change in carbon stocks in the soil organic carbon pool in the baseline scenario for sample field *i* in year *t* based on approved performance benchmark expressed in terms of change in soil organic carbon stocks per unit area per unit time
Equations	Equation 34
Source of data:	Approved performance benchmark
Description of measurement methods and procedures to be applied:	Not applicable
Frequency of monitoring/recording:	Calculations and recording must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	
Purpose of data:	Calculation of emission reductions

[28] http://www.fao.org/soils-portal/soil-survey/sampling-and-laboratory-techniques/en/

Calculation method:	A performance benchmark-derived rate of change in soil organic carbon stocks per unit area is calculated to estimate carbon stocks in the soil organic carbon pool in the baseline scenario for sample field *i* in year *t*.
Comments:	Performance benchmarks for demonstration of the crediting baseline may be established through a revision to this methodology following requirements in the most current versions of the VCS Standard and VCS Methodology Requirements.

Data / Parameter:	$\bar{\Delta}_{\bullet,t}$ and $\bar{\bullet}_t$
Data unit:	t CO_2e/unit area
Description:	Average emission reductions from pool or source •, or stock of pool •, in year *t*
Equations	Equation 32 , Equation 38 , Equation 43 , Equation 49 , and Equation 50
Source of data:	Calculated from modeled or calculated values in the project area
Description of measurement methods and procedures to be applied:	Not applicable
Frequency of monitoring/recording:	Calculations and recording must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	
Purpose of data:	Calculation of emission reductions
Calculation method:	The average emission reductions from pool or source •, or stock of pool •, at time *t* are estimated using unbiased statistical approaches, such as from:

	Cochran, W.G., 1977. Sampling Techniques: 3d Ed. New York: Wiley. It is understood that application of this methodology may employ sample units of unequal sizes, which would necessitate proper weighting of samples in deriving averages. A range of sample designs (e.g., simple random samples, stratified samples, variable probability samples, multi-stage samples) may be employed.
Comments:	None

Data / Parameter:	$\Delta C_{TREE,bsl,i,t}$
Data unit:	t CO_2e/unit area
Description:	Change in carbon stocks in trees in the baseline
Equations	See Section 8.2.2 and Equation 36
Source of data:	Determined in project area
Description of measurement methods and procedures to be applied:	Calculated using the CDM A/R Tools *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities* and *Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands.*
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See description of measurement methods and procedures to be applied
Purpose of data:	Calculation of baseline emissions
Calculation method:	See description of measurement methods and procedures to be applied
Comments:	None

Data / Parameter:	$\Delta C_{SHRUB,bsli,t}$

Data unit:	t CO_2e/unit area
Description:	Change in carbon stocks in shrubs in the baseline
Equations	See Section 8.2.2 and Equation 37
Source of data:	Determined in project area
Description of measurement methods and procedures to be applied:	Calculated using the CDM A/R Tools *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities* and *Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands.*
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See description of measurement methods and procedures to be applied
Purpose of data:	Calculation of baseline emissions
Calculation method:	See description of measurement methods and procedures to be applied
Comments:	None

Data / Parameter:	$\Delta C_{TREE,wp,i,t}$
Data unit:	t CO_2e/unit area
Description:	Change in carbon stocks in trees in the project
Equations	See Section 8.2.2 and Equation 36
Source of data:	Determined in project area
Description of measurement methods and procedures to be applied:	Calculated using the CDM A/R Tools *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities* and *Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands.*

Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See description of measurement methods and procedures to be applied
Purpose of data:	Calculation of project emissions
Calculation method:	See description of measurement methods and procedures to be applied
Comments:	None

Data / Parameter:	$\Delta C_{SHRUB,wp,i,t}$
Data unit:	t CO_2e/unit area
Description:	Change in carbon stocks in shrubs in the project
Equations	See Section 8.2.2 and Equation 37
Source of data:	Determined in project area
Description of measurement methods and procedures to be applied:	Calculated using the CDM A/R Tools *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities* and *Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands.*
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See description of measurement methods and procedures to be applied
Purpose of data:	Calculation of project emissions
Calculation method:	See description of measurement methods and procedures to be applied
Comments:	None

Data / Parameter:	$FFC_{wp,j,i,t}$

Data unit:	Liters
Description:	Consumption of fossil fuel type *j* in the project for sample unit *i* in year *t*
Equations	Equation 4
Source of data:	See Box 1
Description of measurement methods and procedures to be applied:	Fossil fuel consumption can be monitored, or the amount of fossil fuel combusted can be estimated using fuel efficiency (for example l/100 km, l/t-km, l/hour) of the vehicle type and the appropriate unit of use for the selected fuel efficiency (for example km driven if efficiency is given in l/100 km).
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Guidance provided in IPCC, 2003 Chapter 5 or IPCC, 2000 Chapter 8 must be applied
Purpose of data:	Calculation of project emissions
Calculation method:	Fuel efficiency factors can be obtained from the 2019 Refinement to the IPCC 2006 Volume 2 Chapter 3
Comments:	For all equations, the subscript *bsl* must be substituted by *wps* to make clear that the relevant values are being quantified for the project scenario.

Data / Parameter:	$P_{wp,l,i,t}$
Data unit:	Head
Description:	Population of grazing livestock in the project scenario of type *l* in sample unit *i* in year *t*
Equations	Equation 6 , Equation 7 , and Equation 23
Source of data:	See Box 1
Description of measurement methods	Record numbers of grazing livestock by type.

and procedures to be applied:	
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Information will be monitored via direct consultation with, and substantiated with a written attestation from, the farmer or landowner of the sample unit. Any quantitative information (e.g., discrete or continuous numeric variables) on agricultural management practices must be supported by one or more forms of documented evidence pertaining to the selected sample unit and relevant monitoring period (e.g., management logs, receipts or invoices, farm equipment specifications).
Purpose of data:	Calculation of project emissions
Calculation method:	Not applicable
Comments:	For all equations, the subscript *bsl* must be substituted by *wp* to make clear that the relevant values are being quantified for the project scenario.

Data / Parameter:	$Days_{wp,l,i,t}$
Data unit:	Days
Description:	Average grazing days per head in the project scenario inside sample unit *i* for each livestock type *l* in year *t*
Equations	Equation , Equation 7, Equation 23
Source of data:	See Box 1
Description of measurement methods and procedures to be applied:	Record livestock grazing days by type
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Information will be monitored via direct consultation with, and substantiated with a written attestation from, the farmer or landowner of the sample unit. Any quantitative information (e.g., discrete or continuous numeric variables) on agricultural

	management practices must be supported by one or more forms of documented evidence pertaining to the selected sample unit and relevant monitoring period (e.g., management logs, receipts or invoices, farm equipment specifications).
Purpose of data:	Calculation of project emissions
Calculation method:	Not applicable
Comments:	For all equations, the subscript *bsl* must be substituted by *wps* to make clear that the relevant values are being quantified for the project scenario

Data / Parameter:	$MB_{wp,c,i,t}$
Data unit:	Kilograms
Description:	Mass of agricultural residues of type *c* burned in the project for sample unit *i* in year *t*
Equations	Equation 9, Equation 27
Source of data:	See Box 1
Description of measurement methods and procedures to be applied:	Estimate the aboveground biomass of grassland before burning for at least three plots (1m*1m). The difference of the aboveground biomass is the aboveground biomass burnt
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Guidance provided in IPCC, 2003 Chapter 5 or IPCC, 2000 Chapter 8 must be applied.
Purpose of data:	Calculation project emissions
Calculation method:	Not applicable
Comments:	For all equations, the subscript *bsl* must be substituted by *wps* to make clear that the relevant values are being quantified for the project scenario

Data / Parameter:	$M_{wp,SF,i,t}$
Data unit:	t fertilizer
Description:	Mass of N containing synthetic fertilizer applied in the project for sample unit *i* in year *t*
Equations	Equation 14
Source of data:	See Box 1
Description of measurement methods and procedures to be applied:	See Box 1
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Information will be monitored via direct consultation with, and substantiated with a written attestation from, the farmer or landowner of the sample unit. Any quantitative information (e.g., discrete or continuous numeric variables) on agricultural management practices must be supported by one or more forms of documented evidence pertaining to the selected sample unit and relevant monitoring period (e.g., management logs, receipts or invoices, farm equipment specifications).
Purpose of data:	Calculation project emissions
Calculation method:	Not applicable
Comments:	For all equations, the subscript *bsl* must be substituted by *wps* to make clear that the relevant values are being quantified for the project scenario

Data / Parameter:	$M_{wp,OF,i,t}$
Data unit:	t fertilizer
Description:	Mass of N containing organic fertilizer applied in the project for sample unit *i* in year *t*
Equations	Equation 15
Source of data:	See Box 1

Description of measurement methods and procedures to be applied:	See Box 1
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Information will be monitored via direct consultation with, and substantiated with a written attestation from, the farmer or landowner of the sample unit. Any quantitative information (e.g., discrete or continuous numeric variables) on agricultural management practices must be supported by one or more forms of documented evidence pertaining to the selected sample unit and relevant monitoring period (e.g., management logs, receipts or invoices, farm equipment specifications).
Purpose of data:	Calculation project emissions
Calculation method:	Not applicable
Comments:	For all equations, the subscript *bsl* must be substituted by *wps* to make clear that the relevant values are being quantified for the project scenario

Data / Parameter:	$W_{wp,l,i,t}$
Data unit:	kg animal mass/head
Description:	Average weight in the project scenario of livestock type *l* for sample unit *i* in year *t*
Equations	Equation 8
Source of data:	Peer-reviewed published data or expert judgement may be used
Description of measurement methods and procedures to be applied:	See source above
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years

QA/QC procedures to be applied:	The project proponent must justify why the values selected for these parameters results in emission reductions that are conservative
Purpose of data:	Calculation of project emissions
Calculation method:	Not applicable
Comments:	For all equations, the subscript *bsl* must be substituted by *wps* to make clear that the relevant values are being quantified for the project scenario

Data / Parameter:	$MB_{g,wp,i,t}$
Data unit:	t dm
Description:	Annual dry matter, including aboveground and below ground, of N-fixing species *g* returned to soils for sample unit *i* in year *t*
Equations	Equation 20
Source of data:	Aboveground and belowground dry matter in N-fixing species *g* returned to soil may be directly measured, or peer-reviewed published data may be used.
Description of measurement methods and procedures to be applied:	See source above
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	
Purpose of data:	Calculation of project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	$LE_{,t}$

Data unit:	$tCO2e$
Description:	Leakage in year *t*;
Equations	Equation 28, Equation 31
Source of data:	Not applicable
Description of measurement methods and procedures to be applied:	Leakage is equal to zero per the applicability conditions and Section 8.4 of this methodology
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	Not applicable
Purpose of data:	Calculation of project emissions
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	$M\_manure_{prj,l,t}$
Data unit:	tonnes
Description:	Project manure applied as fertilizer on the project area from livestock type *l* in year *t*
Equations	Equation 28
Source of data:	See Box 1
Description of measurement methods and procedures to be applied:	See Box 1
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years

QA/QC procedures to be applied:	See Box 1
Purpose of data:	Calculation of project emissions from leakage
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	$CC_{prj,l,t}$
Data unit:	fraction
Description:	Carbon content of manure applied as fertilizer on the project area from livestock type l in year *t*
Equations	Equation 28
Source of data:	See Box 1
Description of measurement methods and procedures to be applied:	See Box 1
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	See Box 1
Purpose of data:	Calculation of project emissions from leakage
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	ΔP
Data unit:	Percent
Description:	Change in productivity

Equations	Equation 29
Source of data:	Calculated (not applicable)
Description of measurement methods and procedures to be applied:	Not applicable
Frequency of monitoring/recording:	Every 10 years
QA/QC procedures to be applied:	Not applicable
Purpose of data:	Determination of change in crop/livestock productivity for leakage analysis
Calculation method:	See Section 8.4.2
Comments:	None

Data / Parameter:	$P_{wp,p}$
Data unit:	Productivity (e.g., kg) per hectare or acre
Description:	Average productivity for product p during the project period
Equations	Equation 29, Equation 30
Source of data:	Farm productivity (e.g., yield) records
Description of measurement methods and procedures to be applied:	Measured using locally available technologies (e.g., mobile weighing devices, commercial scales, storage volume measurements, fixed scales, weigh scale tickets, etc.)
Frequency of monitoring/recording:	Each growing season
QA/QC procedures to be applied:	See Box 1
Purpose of data:	Determination of project productivity for market leakage analysis

Calculation method:	Not applicable (measured)
Comments:	None

Data / Parameter:	p
Data unit:	Categorical variable
Description:	Crop/livestock product
Equations	Equation 29, Equation 30
Source of data:	See Box 1
Description of measurement methods and procedures to be applied:	Not applicable
Frequency of monitoring/recording:	Each growing season
QA/QC procedures to be applied:	Not applicable
Purpose of data:	Identification of crop/livestock product for market leakage analysis
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	ΔPR
Data unit:	Percent
Description:	Change in productivity ratio
Equations	Equation 30
Source of data:	Calculated (not applicable)
Description of measurement methods	Not applicable

and procedures to be applied:	
Frequency of monitoring/recording:	Every 10 years
QA/QC procedures to be applied:	Not applicable
Purpose of data:	Determination of change in crop/livestock productivity for leakage analysis
Calculation method:	See Section 8.4.2
Comments:	None

Data / Parameter:	$RP_{wp,p}$
Data unit:	Unitless
Description:	Average regional productivity for product p during the same years as the project period
Equations	Equation 30
Source of data:	Regional productivity data from government (e.g., USDA Actual Production History data), industry, published, academic or international organization (e.g., FAO) sources.
Description of measurement methods and procedures to be applied:	Not applicable
Frequency of monitoring/recording:	Every 10 years
QA/QC procedures to be applied:	Not applicable
Purpose of data:	Determination of project productivity ratio for market leakage analysis
Calculation method:	Not applicable
Comments:	None

Data / Parameter:	*$Buffer_{,t}$*
Data unit:	$tCO2e$
Description:	Number of buffer credits to be contributed to the AFOLU pooled buffer account in year *t*
Equations	Equation 53
Source of data:	The number of buffer credits to be contributed to the AFOLU pooled buffer account must be determined by applying the latest version of the *VCS AFOLU Non-Permanence Risk Tool*
Description of measurement methods and procedures to be applied:	Not applicable
Frequency of monitoring/recording:	Monitoring must be conducted at least every five years, or prior to each verification event if less than five years
QA/QC procedures to be applied:	The number of buffer credits to be contributed to the AFOLU pooled buffer account must be determined by applying the latest version of the *VCS AFOLU Non-Permanence Risk Tool*
Purpose of data:	Calculation of project emissions
Calculation method:	The number of buffer credits to be contributed to the AFOLU pooled buffer account must be determined by applying the latest version of the *VCS AFOLU Non-Permanence Risk Tool*
Comments:	None

9.3 Description of the Monitoring Plan

The methodology allows for a range of monitoring approaches, including direct measurement (Quantification Approach 2) as well as the use of models (Quantification Approach 1) and default factors (Quantification Approach 3). Monitored parameters are collected and recorded at the sample unit scale, and emission reductions are estimated independently for every sample unit. The main objective of monitoring is to quantify stock change of soil organic carbon and emissions of CO_2, CH_4, and N_2O resulting from the project scenario during the project crediting period, prior to each verification.

Project proponents must detail the procedures for collecting and reporting all data and parameters listed in Section 9.2. The monitoring plan must contain at least the following information:

- A description of each monitoring task to be undertaken, and the technical requirements therein;
- Definition of the accounting boundary, spatially delineating any differences in the accounting boundaries and/or quantification approaches;
- Parameters to be measured, including any parameters required for the selected model (additional to those specified in this methodology);
- Data to be collected and data collection techniques and sample designs for directly-sampled parameters;
- Modeling plan, if applicable; Anticipated frequency of monitoring, including anticipated definition of “year”;
- 10-year baseline re-evaluation plan, detailing source of regional (sub-national) agricultural production data and procedures to revise the baseline schedule of management activities where necessary;
- Quality assurance and quality control (QA/QC) procedures to ensure accurate data collection and screen for, and where necessary, correct anomalous values, ensure completeness, perform independent checks on analysis results, and other safeguards as appropriate;
- Data archiving procedures, including procedures for any anticipated updates to electronic file formats. All data collected as a part of monitoring process, including QA/QC data, must be archived electronically and be kept at least for two years after the end of the last project crediting period; and
- Roles, responsibilities and capacity of monitoring team and management.

9.3.1 Sample design

It is understood that application of this methodology may employ a range of potential sample designs including simple random samples, stratified samples, variable probability samples, multi-stage samples, etc. The sample design will be specified in the monitoring plan, and un-biased estimators of population parameters identified that will be applied in calculations.

For all direct-sampled parameters, the project monitoring plan will clearly delineate spatially the sample population and specify sampling intensities, selection of sample units and sampling stages (where applicable).

9.3.2 Modeling plan

Where Quantification Approach 1 is applied, the project monitoring plan will identify the model(s) selected initially and document analysis and results demonstrating validation of the model(s). Model validation datasets will be identified and archived to permit periodic application to calculate model prediction error. The modeling plan specify the baseline schedule of agricultural management activities for each sample unit (fixed ex ante). Parameter tables will be developed for all model input variables (un-defined in the methodology) using the tables formats in Section 9.2 above.

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APPENDIX 1: NON-EXCLUSIVE LIST OF POTENTIAL IMPROVED ALM PRACTICES THAT COULD CONSTITUTE THE PROJECT ACTIVITY

Reduced fertilizer application

- Optimized fertilizer application
- Organic fertilizer application (e.g., manure, compost)
- Rice - Urease inhibitor (e.g., NBPT, or controlled release fertilizer)

Improve water management/irrigation

- No irrigation
- Rice - alternative wetting and drying (AWD)

Reduce tillage/improve residue management

- Reduced tillage/no-till
- Continuous no-till
- Crop residue retention

Improve crop planting and harvesting

- Rotational commercial crop
- Continuous commercial crop with cover crop
- Rotational commercial crop with cover crop
- Double cropping
- Relay cropping
- Intercropping of cover crop with commercial crop (e.g., improved agroforestry) during the same growing season

Improve grazing practices

- Rotational grazing (also known as cell and holistic grazing)
- Adaptive multi-paddock grazing (rotational, livestock numbers are adjusted to match available
- forage as conditions change)
- Multi-species grazing
- Grazing of agricultural residues post-harvest and cover crops

APPENDIX 2: RECOMMENDED PROCESS FOR ASSESSING WHETHER NEW PROJECT ACTIVITY INSTANCES ARE COMMON PRACTICE

Section 3.5.15 of the VCS Standard, v4.0[29] sets out the eligibility criteria requirements that grouped projects must develop and include in their project description. These eligibility criteria are a set of project-specific criteria that serve as a screen to determine if any new project activity instances meet the baseline scenario and have characteristics with respect to additionality that are consistent with the initial project activity instances. The addition of new instances does not impact the additionality of the instances already included in the project.

Figure A2.1 outlines a recommended approach for assessing common practice of new project activity instances and identifies when a new weighted average should be calculated (See Section 7 for further details). New instances of any activity or combined activity (i.e., two or more activities on the same field) whose adoption rate on their own (i.e., as single or combined activities) were below 20% in the applicable state/province (or equivalent 2nd order jurisdiction) at validation are automatically deemed additional. New instances of any individual activity or combined activity that were not included in the

29 https://verra.org/wp-content/uploads/2019/09/VCS_Standard_v4.0.pdf

initial assessment of additionality, but with a current existing adoption rate below 20% are also deemed additional.

If the project proponent seeks to add new activities or combined activities that are non-additional on their own (i.e., with single or combined adoption rates greater than 20%) in a given state/province, a new weighted average should be calculated (See Step 2 of Section 7). To calculate the weighted average project proponents should use the total area across the entire project currently under each management activity (i.e., old and new activity instances). Further, on fields where new project activities have been added to existing project activities since the last monitoring period, the combined activity adoption rate should be used. For example, if an area of land entered the project at the outset by adopting cover cropping, and in subsequent years also adopted reduced tillage, the adoption rate for the combined activities (i.e., both activities on a given land area) should be used for that land.

To determine adoption rates for the purpose of re-calculating the weighted average or assessing whether a new practice not previously assessed in a given state/province is common practice, the project proponent should use the most current and high quality data available (See Step 2 of Section 7 for further guidance on appropriate data sources). However, the project proponent may exclude their own activity instances from the adoption rate, so long as those instances have already been deemed additional and have been successfully verified at least once. In this way, the project proponent is not penalized for successful implementation of a given activity in a given region.

If a given activity is deemed common practice in a state/province through a re-calculated weighted average (and therefore considered non-additional if applied on its own), growers that were previously implementing, and being credited for, the activity on a portion of their land should still be eligible to be credited for the expansion of the activity throughout their farm. However, any expansion in activity area should be included in current and future weighted average calculations in relation to eligibility of new growers, which will affect what other activities, may be added without exceeding the 20% threshold.

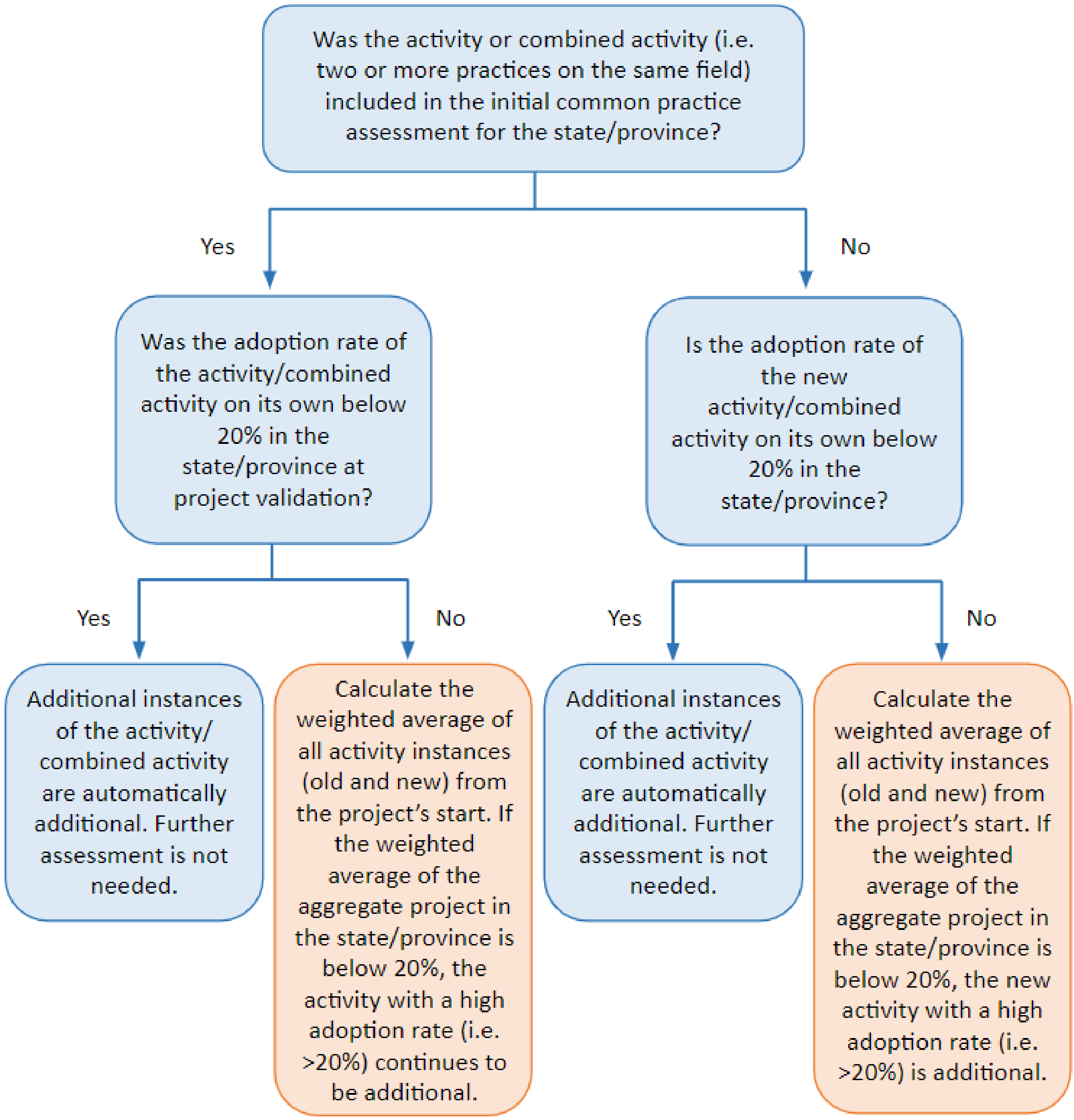

Figure 2. Flowchart for establishing when the weighted average should be re-calculated with the new activity instances for common practice demonstration