Verified Carbon Standard

METHODOLOGY FOR IMPROVED AGRICULTURAL LAND MANAGEMENT

indigo

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Prepared By	TerraCarbon LLC
Contact	Indigo Ag Inc. 500 Rutherford Ave Boston, Massachusetts 02129 TerraCarbon LLC 5901 N Sheridan Rd Peoria, Illinois 61614

Relationship to Approved or Pending Methodologies

Approved and pending methodologies under the VCS and approved GHG programs that fall under the same combination of sectoral scopes and AFOLU project categories were reviewed to determine whether an existing methodology could be reasonably revised to meet the objective of the proposed methodology. Eight methodologies were identified and are set out in Table 1 below. Revision of any one of these methodologies to meet the objective of the proposed methodology would require completely rewriting substantial proportions of the methodology, as described in Table 1. Therefore, it was determined that development of a new methodology was most appropriate.

Overall, ALM methodologies that cover both Improved Cropland Management (ICM) and Improved Grassland Management (IGM) activities are lacking. This broadly applicable ALM methodology captures changes in major pools and sources impacted by improved agricultural land management activities on croplands and grasslands. Project proponents may use modelling to simplify estimation of net emissions of CO_2, CH_4, and N_2O from grower operations.

Table 1: Similar Methodologies

Methodology	Title	GHG Program	Comments
VM0017	Adoption of Sustainable Agricultural Land Management, v1.0	VCS	This methodology applies a simplified baseline, requiring that the area of land under cultivation in the region is constant or increasing in the absence of the project. Revision of the methodology would require rewriting baseline procedures for estimation of soil organic carbon stocks.
VM0021	Soil Carbon Quantification Methodology, v1.0	VCS	This methodology requires direct measurements to quantify changes in SOC stocks. It does not allow modeling of changes in SOC stocks. Revision of the methodology would require rewriting baseline and with project procedures to accommodate modeling.

Methodology	Title	GHG Program	Comments
VM0022	Quantifying N_2O Emissions Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction, v1.0	VCS	This methodology covers N_2O emission reductions resulting from reduction in nitrogen fertilizer application rate in the United States only. Revision of the methodology would require rewriting baseline procedures to allow for application of a project method and expand applicability to include areas outside of the United States.
VM0026	Methodology for Sustainable Grassland Management, v1.0	VCS	This methodology is limited to IGM activities. It cannot be revised to apply to crop production.
VM0032	Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing, v1.0	VCS	This methodology is limited to IGM activities. It cannot be revised to apply to crop production.
AR-ACM0003	Afforestation and reforestation of lands except wetlands v2.0	CDM	This methodology applies to afforestation and reforestation activities. Activities covered by the methodology may impact carbon storage in woody vegetation where the activity does not qualify as afforestation/reforestation. The methodology cannot be revised to apply to activities covered by the new methodology.
	Rice Cultivation Project Protocol v1.1	CAR	This methodology is only applicable to the California Sacramento Valley rice growing region. This methodology is only applicable to rice production. It cannot be revised to apply to crops other than rice or livestock production.
	Nitrogen Management Project Protocol v2.0	CAR	This methodology is only applicable in the United States. Revision of the methodology would require rewriting additionality procedures to allow for application of the methodology in areas outside of the United States.

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1 SOURCES

This methodology is based on the following VCS methodologies:

- *VM0017 Adoption of Sustainable Agricultural Land Management*
- *VM0022 Quantifying N_2O 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

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

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

[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.

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 re-evaluated as required by the VCS Standard, and revised, if necessary, to reflect current agricultural commodity 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 A), 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:

- 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.
- 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.
- 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 8.1. 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 8.1.

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 Box 4.1).

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 9.1 repeated over the baseline period and apply to relevant model input variables (see Table 6.1 and 8.3) and parameters $FFC_{bsl,j,i,t}$, $P_{bsl,l,i,t}$, $Days_{bsl,l,i,t}$, $M_{bsl,SF,i,t}$, $M_{bsl,OF,i,t}$, $H_{bsl,l,i,t}$, and $MB_{g,bsl,i,t}$, etc.

Synthetic nitrogen fertilizer
Any synthetic fertilizer (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 CO_2, CH_4, and N_2O 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 agriculture 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.

    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 (i.e., land use change is not eligible), and remains in agricultural production throughout the project crediting period.
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 (i.e. over at least 10 consecutive years from the project start date, supported by peer-reviewed and/or published studies) in productivity or sustained displacement of any pre-existing productive activity in the project area;
5. The project activity must not involve significant displacement of livestock outside of the project area, and safeguards must be in place to avoid unintended displacement of livestock outside of the project area caused by the project activity (e.g., fencing, grazing forages). Significance must be demonstrated via *de minimis* demonstration. 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.*[2]

This methodology is not applicable under the following conditions:

6. 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) 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);
4) Validated per datasets and procedures detailed in Box 4.1, with model structural uncertainty calculated using datasets as detailed in Box 4.1, using the same parameters or sets of parameters applied to estimate stock change/emissions in the project.

[2] 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.

Box 4.1. Model validation requirements

Model validation requires showing a lack of bias or conservative bias for modeled SOC stock change and, if using Quantification Approach 1, flux change of N_2O and CH_4, when adopting eligible practices. Model validation steps are as follows:

Step 1) Declare the practice effects requiring evaluation for the project

For every practice considered additional within the project, the model must be shown to have an unbiased or conservatively biased representation of the underlying biogeochemical process governing the effect of that practice. To do so, each practice must be binned into the following categories.

Practice Category	Practice Effect Requiring Evaluation
Inorganic Nitrogen fertilizer application	Magnitude, form, or method for nitrogen fertilizer applied, with form encompassing inorganic and organic N fertilizers, and method encompassing surface, subsurface, or irrigation-based application
Organic amendments application	Magnitude, form, method or variation in C:N ratio for organic amendments applied. Forms include and are not limited to biochar, mulch, compost, and manure, and methods encompass surface, subsurface, or irrigation-based application
Water management/irrigation	Magnitude, timing, source, or method of irrigation water applied
Soil disturbance and/or residue management	Soil disturbance including tillage and compaction, residue management encompassing soil exposure after harvest
Cropping practices, planting and harvesting (e.g. crop rotations, cover crops)	Variety of crops grown, increasing crop rooting depth, which may include cover crops, and soil preparations such as changing soil pH through liming
Grazing practices	Any of the following: presence/absence of grazing, stocking density, forage type or quality, species of grazers, mixed or single species herds, loading weight, grazing time, and rest/recovery periods

All categories for which adopted practice changes will be quantified for crediting as well as the associated practice effects that require evaluation must be declared. Evaluation must be demonstrated using the following steps.

Step 2) Define the project domain

Unique crop types must be declared, as well as soil textural classes, and climate zones across all practice categories declared in Step 1.

2.A. Identify Groupings of Unique Crop Types

The full list of crop types to be included in the project must be declared. Crop types can be grouped into bins across crops sharing unique combinations of the following attributes:

- N fixation (Y/N),
- annual/perennial (A/P) (defined in accordance with the NRCS Conservation Compliance categorization of crops, found here),
- photosynthetic pathway (C3/C4/CAM),
- tree/shrub/herbaceous (trees and shrubs have woody plant growth, versus herbaceous species that do not grow woody plant material), and/or
- flooded/not flooded

2.B. Soil Textural and Clay Attributes

Two soil attributes should be declared for each practice effect requiring evaluation in the project. One is the list of NRCS soil textural classes where these practice effects will occur, while the second is the highest and lowest % clay values in the same areas. NRCS soil texture classes include: sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, clay.

2.C. Climate Zones

For each practice category, the full list of Climate Zones encompassed in the project domain must be declared, following the climate zone definitions given in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Step 3) Gather validation data that meet the following requirements

Requirement 1: Validation datasets for each declared practice category effect requiring evaluation from Step 1 must be assembled for each modeled quantity, where the modeled quantity is the *change* in SOC stock and/or seasonal/annual N_2O and CH_4 flux (if applicable) with adoption of practices within a category. Datasets may include individual practice effects as well as combinations of practice effects (e.g. “stacked” practices), provided the practice effect in question is experimentally varied and measured within the study. Some hypothetical examples of acceptable experimental treatments to evaluate practice effects include:

Practice Effect	Experimental treatment
Magnitude of nitrogen fertilizer applied	Comparison of two different application rates of urea; comparison of inorganic N fertilizer to manure.
Soil disturbance	Comparison of conventional tillage using moldboard plow to strip tillage.
Variety of crops grown	Comparison of single-crop rotation to double-crop rotation; comparison of no cover-crop to with cover crop.

Validation data must adhere to the following guidelines:

1. Measured datasets must be drawn from peer-reviewed and published experimental datasets with measurements of SOC stock change (and annual/seasonal measures of N_2O and CH_4 change if applicable) using control plots to test the practice effect requiring evaluation. All dataset sources must be reported. The same measurement dataset sources can be used for model validation across practice effects, if applicable to more than 1 practice effect requiring evaluation.

2. In the case of SOC stocks, measurements of SOC stock changes must be statistically robust capture multi-year changes, as practice effects on SOC may combine short- and long-term changes in soil biogeochemical processes. For example, the use of data from repeat measurements of bulk SOC through time or measures of paired fields using space-for-time substitution typically must span or approximate at least a 5-year interim, with longer time intervals needed with some practices and geographies to demonstrate statistically significant SOC changes. Newer methods for SOC stock monitoring are becoming available that can observe changes with greater precision and at shorter time intervals, and are acceptable if there is peer-reviewed support for their use in SOC monitoring, and demonstrate statistically robust evaluation of multi-year impacts on SOC stock changes. In the case of annual/season measured sources for changes in N_2O and CH_4 flux resulting from practice effects, any combination of measurements from chambers and/or eddy covariance flux towers are acceptable.

3. Datasets may be drawn from a benchmark database that reports dataset sources, maintained by a 3rd party and, approved by the Global Soils Partnership (or comparable).

4. Project proponents should describe the methods, selection process, and data manipulations used to create the dataset applied in the model validation process. This includes describing search terms and databases used to identify available datasets, criteria used to select dataset sources, origin of extracted data (e.g. figures,

tables, databases), original units of data, and data manipulations used to convert original units into the units described above. The project proponent should report the number of validation data measurements of each data type (SOC, N_2O and CH_4) for each project domain combination of climate zones, soils textures and crop types. The project proponent should also report how the project area is distributed across the project domain in each of these project domain combinations. In the case where validation data are unevenly distributed compared to how the project area is distributed, the method used to link validation data to model structural error (described in more detail below) should demonstrate that it addresses the discrepancy.

Requirement 2: Validating a practice effect for the entire project domain can only be completed if there are measurements of SOC stock and annual/seasonal N_2O and CH_4 flux change (if applicable), that in total cover:

- at least three soil-climate zones included in the project domain;
- soils that fall within the types of textural classes and range of clay percentages in the project domain, including no less than three different soil textural classes and enough variance in clay content such that the highest and lowest are at least 15 percentage points apart. Soil textural classes are defined using the following NRCS classifications: sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay.
- all crop types included in the project domain associated with that practice effect.

It is in a project's interest to exceed these minimums and validate the model across more soil-climate zones, soil texture classes, and clay contents, as model prediction error should use the same dataset as model validation, and is required to penalize the use of few data points (see below on Linking validation data to model structural error).

Step 3) Use model performance criteria to demonstrate lack of bias or conservative bias for each eligible practice

For each practice effect declared in Step 1, the model must be shown to be unbiased or conservatively biased in estimating the change in SOC, N_2O, or CH_4 for the project domain defined in Step 2, using measured data that meet the requirements of Step 3. This is done using a calculation of bias, a simplified version of average relative error or (FAO 2019, Yang et al. 2014) calculated between measured data and model prediction. Bias must be calculated for each individual experimental study, since different studies may use different temporal units of aggregation, soil depths, or measurement techniques. The calculation of bias is defined as:

$$bias = \sum_{i=1}^{n}(P_i - O_i)$$

Where:

P_i is the predicted (modeled) value of change in SOC, N_2O, or CH_4 with the practice, and

O_i is the observed value of change in SOC, N_2O, or CH_4 with the practice.

Bias indicates the average tendency of the modeled estimates to be larger or smaller than their observed counterparts (Moriasi et al. 2007). An unbiased model will have bias = 0.0. Positive values indicate model overestimation bias, meaning that the model overestimates the practice effect and thus the credits earned. A negative value indicates model underestimation bias, or an underestimation of the credits earned. To ensure the model is conservatively biased, bias must be shown to be ≤<= 0.0. Sufficient model validation requires the model to be unbiased or conservatively biased for each study examined, i.e. bias must be shown to be ≤<= 0.0 in all cases.

Linking validation data to model structural error

The same data should be used for model validation and in the calculation of model structural error (equation 42). The model structural error calculation should be shown to penalize fewer data points (e.g., by using a weakly informative prior; see Equation 42) and account for data variability (i.e. with a wider posterior when data are more variable), such that the uncertainty deduction in credits is higher when fewer or more variable data are available. Thus, in addition to demonstrating lack of bias or conservative bias, these guidelines require that both model accuracy and precision be quantitatively accounted for in the calculation of credits.

In the model validation report (described below), the following should be included for each practice effect/crop type combination and for changes in SOC, N_2O, and CH_4:

- the measured versus model predictions
- number and variance of the measured values
- model prediction error

Satisfying the model validation requirements: reporting and via peer-review

A model validation report following the above guidance should be submitted showing that model validation requirements have been satisfied and confirmed prior to the completion of verification activities. An acceptable form of confirmation is review and approval from an organization supporting the use of models for climate smart agriculture, including or comparable to the Global Soils Partnership, FAO, or UN Convention to Combat Desertification.

It is also acceptable that the validation report is submitted as a peer-reviewed journal article, provided that the journal is on the pre-approved list provided below. It is acceptable that the journal article has not yet been printed as long as it has passed peer review and has been accepted for publication with revisions that do not change any aspects of model validation. In this circumstance, the project should submit the peer reviewed publication and responses to all revisions that clearly demonstrate revisions do not impact model validation. Where the peer-review publication option isn pursued, it is additionally acceptable that model validation is completed using a different method than explicitly evaluating bias as described above. In lieu of explicitly evaluating bias as described above, successful model validation may be demonstrated through publication in a peer-reviewed journal. In this case, the same model version and model parameter values/parameter set values must be used in the peer-reviewed publication as are used in the project. The publication must demonstrate that separate datasets were used to for model calibration/parameterization and model validation. The model validation must demonstrate the model was found acceptable for use by the peer reviewers for a given biophysical domain and a given set of practices. Additionally, the biophysical domain and practices used in the publication must be shown to completely meet the same domain requirements laid out in Steps 2 and 3, as well as cover the practice effects identified in Step 1. The same datasets used in the peer-reviewed model validation should be used to calculate model structural uncertainty used in the project.

Approved peer-review journals

- Global Change Biology
- Global Biogeochemical Cycles
- Agriculture, Ecosystems and Environment
- Agricultural Systems
- Biogeosciences
- Biogeochemistry
- Environmental Modelling and Software
- Ecological Modeling
- Journal of Geophysical Research - Biogeosciences
- Soil Biology & Biochemistry
- Soil & Tillage Research
- Atmospheric Environment
- Nutrient Cycling in Agroecosystems
- Ecosystems
- Science of the Total Environment
- PLoS ONE
- Journal of Environmental Quality
- Frontiers in Ecology and the Environment

Substitution for Missing Crop Types

If during the calibration and validation process no sufficient data are available for a declared crop type, a substitution may be made that entails specific replacements be made for the baseline and with-project simulations. This method depends on the availability of alternative crop types for a given practice effect that meet all of the above criteria; without any alternatives no substitution can be made.

Baseline:

- Replace the missing crop type with an unfertilized perennial grass;

Project:

- Replace the missing crop type with an alternative crop type for which data are available that best matches the missing crop in terms of its attributes, i.e., N fixation, annual/perennial, photosynthetic pathway, plant form, and flooded/not flooded status. The acceptable alternative crop will have the most matching categories among all crop types available.
- For multiple alternative crop types having the same number of matching attributes, the crop type that best accommodates the management practices of the missing crop should be selected.

Step 4) Use model performance criteria to demonstrate lack of bias or conservative bias for each eligible practice

For each practice effect declared in Step 1, the model must be shown to be unbiased or conservatively biased in estimating the change in SOC, N_2O, or CH_4 for the project domain defined in Step 2, using measured data that meet the requirements of Step 3. This is done using calculation of bias, a simplified version of average relative error or (FAO 2019, Yang et al. 2014) calculated between measured data and model prediction. Bias must be calculated for each individual experimental study, since different studies may use different temporal units of aggregation, soil depths, or measurement techniques. The calculation of bias is defined as:

$$\text{bias} = \sum_{i=1}^{n} P_i - O_i$$

where:

P_i is the predicted (modeled) value of change in SOC, N_2O, or CH_4 with the practice, and
O_i is the observed value of change in SOC, N_2O, or CH_4 with the practice.
Bias indicates the average tendency of the modeled estimates to be larger or smaller than their observed counterparts (Moriasi et al. 2007). An unbiased model will have bias = 0. Positive values indicate model overestimation bias, meaning that the model overestimates the practice effect and thus the credits earned. A negative value indicates model underestimation bias, or an underestimation of the credits earned. To ensure the model is conservatively biased, bias must be shown to be ≤ 0. Sufficient model validation requires the model to be unbiased or conservatively biased for each study examined, i.e. bias must be shown to be ≤ 0 in all cases.

Linking validation data to model structural error

The same data should be used for model validation and in the calculation of model structure error (equation 42). The model structural error calculation should be shown to penalize fewer data points (e.g., by using a weakly informative prior; see Equation 42) and account for data variability (i.e. with a wider posterior when data are more variable), such that the uncertainty deduction in credits is higher when fewer or more variable data are available. Thus, in addition to demonstrating lack of bias or conservative bias, these guidelines require that both model accuracy and precision be quantitatively accounted for in the calculation of credits.

In the model validation report (described below), the following should be included for each practice effect/crop type combination and for changes in SOC, N_2O, and CH_4:

- the measured versus model predictions
- number and variance of the measured values
- model prediction error

Satisfying the model validation requirements: reporting and peer-review

A model validation report following the above guidance should be submitted showing that model validation requirements have been satisfied and confirmed prior to the completion of verification activities. An acceptable form of confirmation is review and approval from an organization supporting the use of models for climate smart agriculture, including or comparable to the Global Soils Partnership, FAO, or UN Convention to Combat Desertification.

It is also acceptable that the validation report is submitted as a peer-reviewed journal article, provided that the journal is on the pre-approved list provided below. It is acceptable that the journal article has not yet been printed as long as it has passed peer review and has been accepted for publication with revisions that do not change any aspects of model validation. In this circumstance, the project should submit the peer reviewed publication and responses to all revisions that clearly demonstrate revisions do not impact model validation. Where the peer-review publication option is pursued, it is additionally acceptable that model validation is completed using a different method than explicitly evaluating bias as described above. In this case, the same model version and model parameter values/parameter set values must be used in the peer-reviewed publication as are used in the project. The publication must demonstrate that separate datasets were used for model calibration/parameterization and model validation. The model validation must demonstrate the model was found acceptable for use by the peer reviewers for a given biophysical domain and a given set of practices. Additionally, the biophysical domain and practices used in the publication must be shown to completely meet the same domain requirements laid out in Steps 2 and 3, as well as cover the practice effects identified in Step 1. The same datasets used in the peer-reviewed model validation should be used to calculate model structural uncertainty used in the project. Lastly, as a means of enhancing transparency with the peer reviewers, the authors must clearly state the purpose of the paper as being to validate the model for use in generating verifiable carbon credits.

Approved peer-review journals
• Global Change Biology • Global Biogeochemical Cycles • Agriculture, Ecosystems and Environment • Agricultural Systems • Biogeosciences • Biogeochemistry • Environmental Modelling and Software • Ecological Modeling • Journal of Geophysical Research - Biogeosciences • Soil Biology & Biochemistry • Soil & Tillage Research • Atmospheric Environment • Nutrient Cycling in Agroecosystems • Ecosystems • Science of the Total Environment • PLoS ONE • Journal of Environmental Quality • Frontiers in Ecology and the Environment

The same model version and parameters/parameter sets must be used in both the project and baseline scenarios. Model input data must be derived following guidance in Table 8.2 (Section 8.2) and Table 8.3 (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 5.1 below.

Table 5.1: Selected Carbon Pools in the Baseline and Project Scenario

Source	Included?	Justification/Explanation
Aboveground woody biomass	Yes	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.*
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	Yes	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 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.
Litter	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.
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 5.2 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).

Table 5.2: 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 5.1).
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 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 species must be included in the project boundary.
Biomass burning	CH_4	S*	

Source	Gas	Included?	Justification/Explanation
	N_2O	S*	

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

The baseline scenario assumes the continuation of pre-project agricultural management practices. 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 commodity 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 6.1 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 9.1.

Table 6.1. 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)

Agricultural management practice	Qualitative	Quantitative
Nitrogen fertilizer application	• Manure (Y/N) • Compost (Y/N) • Synthetic N fertilizer (Y/N)	• Manure application rate (if applicable) • Compost application rate (if applicable) • Synthetic N fertilizer application rate (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 (if applicable)

In most cases, quantitative information is associated with related qualitative information (see Box 9.1). 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 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 6.1 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.*

The most plausible baseline scenario is derived in Section 6 above as the continuation of pre-project agricultural management activities. The project activity is defined as the adoption, at the project start date, of one or more changes in pre-existing agricultural management 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 to demonstrate additionality.

In addition, project proponent(s) must identify barriers that would prevent the implementation of a change in pre-existing agricultural practices at the project area scale (i.e., not for each individual instance of a grouped project) and at the national or regional agricultural sector scale (i.e. not for individual agricultural management practices).

STEP 1. Identify barriers that would prevent the implementation of a change in pre-existing agricultural management practices as opposed to the continuation of pre-project agricultural management activities

The project proponent must determine whether the proposed change or changes in agricultural management practices expected to reduce GHG emissions and/or increase GHG removals face barriers related to cultural practices and social norms, attitudes and beliefs that prevent the implementation of a change in pre-existing agricultural management practices without the revenue from the sale of VCUs.

The project proponent must list and describe barriers to implementation of a change or changes proposed to pre-existing agricultural management practices to establish that there are cultural and/or social barriers that would prevent the implementation of a change in pre-existing agricultural management practices from being carried out if the project was not registered as a VCS project. Demonstration of barriers will 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.
- Barriers associated with grower identity.

STEP 2. Demonstrate that the adoption of the suite of proposed improved agricultural land management activities is not common practice

The project proponent must determine whether the proposed change or changes in agricultural management activities expected to reduce GHG emissions and/or increase GHG removals are common practice in the region where the project is located. Common practice is assessed against the extent to which the improved agricultural land management activity, or suite of activities[3], to be implemented across the project is/are already being practiced in the region.

To demonstrate that a project activity, or suite of activities, is not common practice (i.e. the predominant practice(s) in a given region) a project proponent must provide one or more of the following forms of evidence:

1. Peer-reviewed scientific literature;
2. Government or independent research data (e.g. census data, research data, survey data, etc.); and/or
3. A signed and dated attestation statement from a qualified independent local expert (e.g. extension agent).

If a project is implemented at a national scale, the project proponent may provide country level data or peer-reviewed science. If a project is limited to a specific geographical area within a country, the project proponent must provide data or peer-reviewed science at the corresponding geographical scale (e.g. province, state, region, etc.). If such supporting data or other evidence is not available (e.g. in developing countries) justification may be provided to use evidence from a larger geographical scale.

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

[3] The suite of activities refers to all practices implemented across the grouped project. It does not refer to the specific practices implemented on each individual 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. 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 8.1. 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, either approach may be used, provided that the same approach is used for both the project and baseline scenarios.

Table 8.1: 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
CH_4	Soil methanogenesis	X		
	Enteric fermentation			X
	Manure deposition			X
	Biomass burning			X
N_2O	Use of nitrogen fertilizers	X		X
	Use of nitrogen fixing species	X		X
	Manure deposition			X

GHG/Pool	Source	Quantification Approach 1: Measure and Model*	Quantification Approach 2: Measure and Remeasure	Quantification Approach 3: Default
	Biomass burning			X

* Approach 1 may only be used if a valid model is available (see model requirements in Box 4.1).

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:

- *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.

- *Quantification Approach 2: Measure and Remeasure*

  Relevant where models are unavailable or have not yet been validated or parameterized. Where an applicable performance benchmark exists, the baseline is equal to the performance benchmark. Quantification Approach 2 is only applicable to SOC.

- *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.

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 8.2.

Table 8.2. 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 $SOC_{wp,i,t=0}$. At time *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.
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 a continuously-monitored weather station within 50 km of the sample field, or from a synthetic weather station (e.g. PRISM[4]).

Quantification Approach 2

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

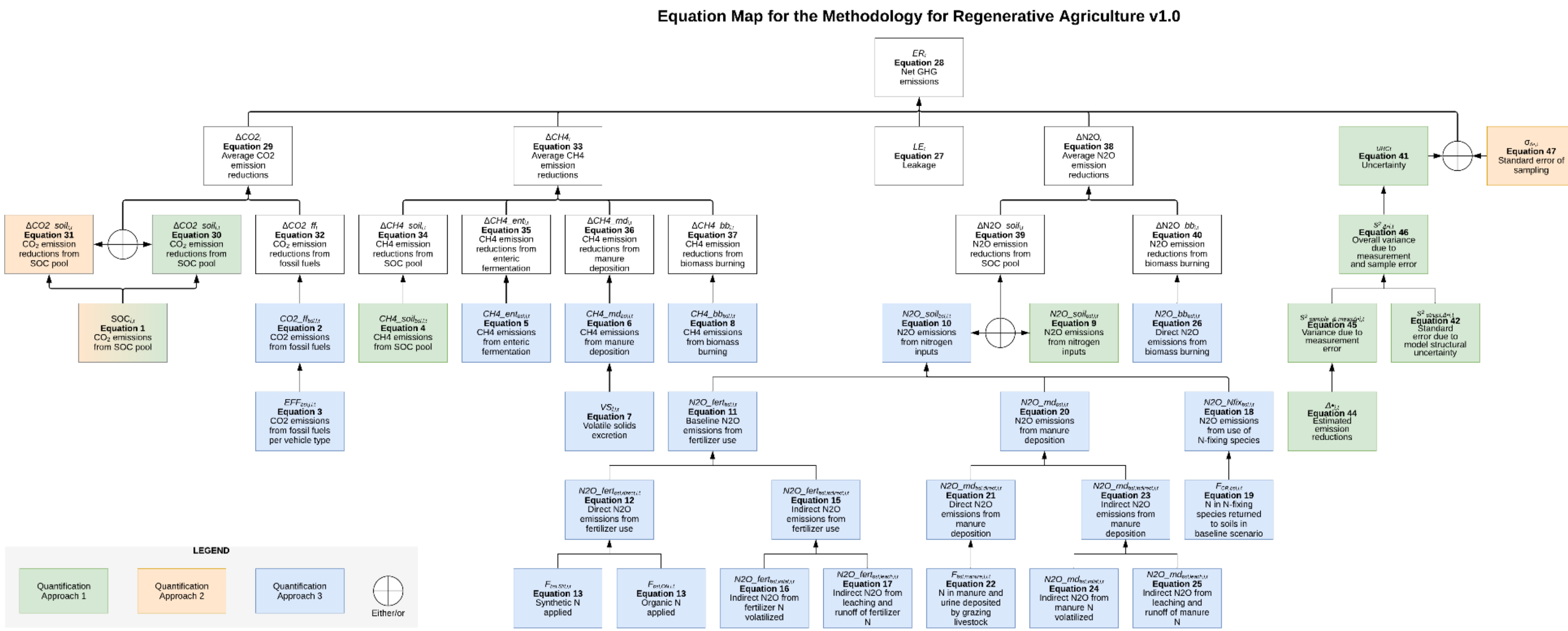
Quantification Approach 3

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 8.1 below

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

Figure 8.1. Equation map of the Improved Agricultural Land Management Methodology.



8.2.1 Soil Organic Carbon Stocks

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

Equation 1

$$SOC_{bsl,i,t} = f_{SOC}\left(Var\ A_{bsl,i,t}, Var\ B_{bsl,i,t}, \dots\right)$$

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)
f_{SOC}	Model predicting carbon dioxide emissions from the soil organic carbon pool (tCO_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)
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 5.2, change in carbon stocks in trees ($\Delta C_{TREE,bsl,i,t}$) and shrubs ($\Delta C_{SHRUB,bsl,i,t}$) 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 5.2, they are quantified in the baseline scenario under Approach 3, using Equation 2 and Equation 3 below:

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

Equation 2

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

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

$EFF_{bsl,i,j,t}$ 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

j Type of fossil fuel (gasoline or diesel)

i Sample unit

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

Equation 3

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

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 in vehicle/equipment 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 5.2, they are quantified in the baseline scenario under approach 1 using Equation 4.

Equation 4

$$CH4soil_{bsl,i,t} = GWP_{CH4} \times f_{CH4SOC}(Var\ A_{bsl,i,t}, Var\ B_{bsl,i,t}, \dots) \times A_i$$

Where:

$CH4\_soil_{bsl,i,t}$ Methane emissions from soil organic carbon pool in the baseline scenario for sample unit *i* in year *t*; tCO_2e

f_{CH4SOC} Model predicting methane emissions from the soil organic carbon pool; tCH_4e/unit area

$Var\ A_{bsl,i,t}$ Value of model input variable A in the baseline scenario for sample unit *i* in year t; units unspecified

$Var\ B_{bsl,i,t}$ Value of model input variable B in the baseline scenario for sample unit *i* in year t; units unspecified

GWP_{CH4} Global warming potential for CH_4

A_i Area of sample unit *i*; unit area

i Sample unit

8.2.5 Methane Emissions from Livestock Enteric Fermentation

If methane emissions from livestock enteric fermentation are included per Table 5.2, they are quantified in the baseline scenario under approach 3 using Equation 5.

Equation 5

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

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

$P_{bsl,l,i,,t}$ Population of grazing livestock in the baseline scenario of type *l* in sample unit *i* in year *t;* head

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

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 5.2, they are quantified in the baseline scenario under approach 3 using Equation 6 and Equation 7.

Equation 6

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

Where:

$CH4\_md_{bsl,i,t}$ Baseline CH_4 emissions from manure deposition in the baseline scenario for sample unit *i* at time *t*; t CO_2e

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)

$Days_{bsl,i,l,t}$ Average grazing days per head in the baseline scenario in sample unit *i* for each livestock type *l* 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)

l Type of livestock

i Sample unit

10^6 Grams per tonne

Equation 7

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

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 5.2, they are quantified in the baseline scenario under approach 3 using Equation 8.

Equation 8

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

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

$MB_{bsl,c,i,t}$ 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

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 5.2, they are quantified in the baseline scenario under approach 1 or approach 3. If quantified under approach 1, Equation 9 is used. If quantified under approach 3, Equation 10 is used.

8.2.8.1 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 9

$$N2Osoil_{bsl,i,t} = f_{N2Osoil}(Var\ A_{bsl,i,t}, Var\ B_{bsl,i,t}, \ldots) \times A_i$$

Where:

$N2O\_soil_{bsl,I,t}$ 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

$f_{N2Osoil}$ Model predicting nitrous oxide emissions (summed across the reporting period for sample unit *i*); t N2O/unit area

$Var\ A_{bsl,i,t}$ Value of model input variable A in the baseline scenario for sample unit *i* in year t; units unspecified

$Var\ B_{bsl,i,t}$ Value of model input variable B in the baseline scenario for sample unit *i* in year t; units unspecified

A_i Area of sample unit *i*; unit area

i Sample unit

8.2.8.2 Quantification approach 3:

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

Equation 10

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

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
$N2Ofert_{bsl,i,t}$	Nitrous oxide emissions due to fertilizer use in the baseline scenario for sample unit *i* in year *t*; t CO_2e
$N2Omd_{bsl,i,t}$	Nitrous oxide emissions due to manure deposition in the baseline scenario for sample unit *i* in year *t*; t CO_2e
$N2ONfix_{bsl,i,t}$	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
i	Sample unit

Under approach 3, if nitrous oxide emissions due to fertilizer use are included in the project boundary per Table 5.2, they are quantified in the baseline scenario using Equations 11, 12, 13, 14, 15, 16, 17.

Equation 11

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

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

Under approach 3 direct nitrous oxide emissions due to fertilizer use_in the baseline scenario are quantified in Equations 12, 13, and 14.

Equation 12

$$N2Ofert_{bsl,direct,i,t} = \left(F_{bsl,SN,i,t} + F_{bsl,ON,i,t}\right) \times EF_{Ndirect} \times 44/28 \times GWP_{N2O}$$

Equation 13

$$F_{bsl,SN,i,t} = M_{bsl,SF,i,t} \times NC_{bsl,SF}$$

Equation 14

$$F_{bsl,ON,i,t} = M_{bsl,OF,i,t} \times NC_{bsl,OF}$$

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
$F_{bsl,SN,bsl,i,t}$	Baseline synthetic N fertilizer applied for sample unit *i* in year *t*; t N
$F_{bsl,ON,bsl,i,t}$	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 applied for sample unit *i* in year *t;* t fertilizer
$M_{bsl,OF,i,t}$	Mass of baseline N containing organic fertilizer applied for sample unit *i* in year *t*; t fertilizer
$NC_{bsl,SF}$	N content of baseline synthetic fertilizer applied; t N/t fertilizer
$NC_{bsl,OF}$	N content of baseline organic fertilizer 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
GWP_{N2O}	Global warming potential for N_2O
i	Sample unit

Under approach 3 indirect nitrous oxide emissions due to fertilizer use in the baseline scenario are quantified in Equations 15, 16, and 17.

Equation 15

$$N2Ofert_{bsl,indirect,i,t} = N2Ofert_{bsl,volat,i,t} + N2Ofert_{bsl,leach,i,t}$$

Equation 16

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

Equation 17

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

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

$N2O\_fert_{bsl,volat,i,t}$ — 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. Value = 0 where average annual precipitation is less than potential evapotranspiration unless subject to irrigation.

$F_{bsl,SN,bsl,i,t}$ — Baseline synthetic N fertilizer applied for sample unit *i* in year *t*; t N

$F_{bsl,ON,bsl,i,t}$ — 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 that volatilizes as NH_3 and NO_x; dimensionless

$Frac_{LEACH}$ — Fraction of N added (synthetic or organic) to soils that is lost through leaching and runoff, in regions where leaching and runoff occurs; 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)

EF_{Nleach} — Emission factor for nitrous oxide emissions from leaching and runoff; t N2O-N / t N leached and runoff

GWP_{N2O} — Global warming potential for N_2O

i — Sample unit

If nitrous oxide emissions due to the use of N-fixing species are included in the project boundary per Table 5.2, they are quantified in the baseline scenario under approach 3 using Equation 18 and Equation 19.

Equation 18

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

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

$F_{CR,bsl,,i,t}$ 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

GWP_{N2O} Global warming potential for N_2O

i Sample unit

Equation 19

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

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 5.2, they are quantified in the baseline scenario under approach 3 using Equations 20, 21, 22, 23, 24..

Equation 20

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

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

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

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

l Type of livestock

i Sample unit

Direct nitrous oxide emissions due to manure deposition in the baseline scenario are quantified using Equations 19 and 20.

Equation 21

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

Equation 22

$$F_{bsl,manure,l,i,t} = \frac{P_{bsl,l,i,t} \times W_{bsl,l,i,t} \times Nex_l \times H_{bsl,l,i,t} \times Days_{bsl,l,i,t}}{10^6 \times 24}$$

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
$F_{bsl,manure,l,i,t}$	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
$W_{bsl,l,i,t}$	Average weight in the baseline scenario of livestock type *l* for sample unit *i* in year *t*; kg livestock mass/head
$H_{bsl,l,i,t}$	Average grazing hours per day in the baseline scenario for livestock type *l* in sample unit *i* in year *t*; hours
$Days_{bsl,l,i,t}$	Average grazing days per head in the baseline scenario for livestock type *l* in sample unit *i* in year *t*; days
N_ex_l	Nitrogen excretion of livestock type *l*; kg N deposited/(t livestock mass * day)
$EF_{N2O,md,l}$	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
l	Type of livestock
i	Sample unit

Indirect nitrous oxide emissions due to manure deposition in the baseline scenario are quantified under approach 3 using Equations 21, 22 and 23.

Equation 23

$$N2Omd_{bsl,indirect,i,t} = N2O_m d_{bsl,volat,i,t} + N2O_m d_{bsl,leach,i,t}$$

Equation 24

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

Equation 25

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

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
$N2O\_md_{bsl,volat,i,t}$	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
$Frac_{GASMD}$	Fraction of 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
$Frac_{LEACHMD}$	Fraction of N in manure and urine deposited on soils that is lost through leaching and runoff, in regions where leaching and runoff occurs; dimensionless
EF_{Nleach}	Emission factor for nitrous oxide emissions from leaching and runoff; t N2O-N / t N leached and runoff
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 approach 3.

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

Equation 26

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

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
$MB_{bsl,c,i,t}$	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
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.

Quantification Approach 1

Model inputs must be collected following guidance in Table 8.3.

Table 8.3. 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 a continuously-monitored weather station within 50 km of the sample field, or from a synthetic weather station (e.g. PRISM[5]).
Agricultural management activities (as identified following procedures in Box 4.1, 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

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

Model Input Category	Timing	Approach
		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.

Quantification Approach 3

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

8.4 Leakage

It is assumed there is zero leakage given the methodology applicability conditions.[6]

Equation 27

$$LE_t = 0$$

Where:

LE_t	Leakage in year t, equal to zero; t CO_2e

[6] Under the methodology applicability conditions, the project activity must not result in a sustained reduction (over >10 years from the project start date) in productivity or sustained displacement of any pre-existing productive activity in the project area. The requirement that the project activity does not result in sustained reduction in productivity ensures that there is no increase in emissions outside of the project area as a result of intensification production elsewhere to compensate for decreased productivity inside the project area. The requirement that the project activity does not result in displacement of any pre-existing productive activity in the project area ensures that there is no increase in emissions outside of the project area that results from shifting pre-existing productive activities to areas outside of the project boundaries.

8.5 Net GHG Emission Reductions and Removals

Net emission reductions and removals are quantified as:

Equation 28

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

Where:

ER_t	Estimated net GHG emissions reductions and removals in year *t*; t CO_2e
A_0	Project area*;* unit area
$\overline{\Delta CO2_t}$	Average[7] carbon dioxide emission reductions in year *t*; t CO_2e/unit area
$\overline{\Delta CH4_t}$	Average methane emission reductions in year *t*; t CO_2e/unit area
$\overline{\Delta N2O_t}$	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 ($\overline{\Delta \boldsymbol{CO2_t}}$)

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 29

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

Where:

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

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

Equation 30

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

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
$SOC_{bsl,i,,t}$	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
i	Sample unit

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:

Equation 31

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

Where:

$\Delta CO2\_soil_{i,t}$	Estimated carbon dioxide emission reductions from soil organic carbon pool for sample unit *i* in year *t*; t CO_2e/unit area
$SOC_{wp,i,t}$	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
$SOC_{wp,i,t-1}$	Estimated 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
$\Delta SOC_{bsl,i,t}$	Estimated temporal change in the carbon stocks in the soil organic carbon pool in the baseline scenario for sample field *i* in year *t* based on performance benchmark; t CO_2e/unit area
i	Sample unit

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

Equation 32

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

Where:

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

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

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

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 33

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

Where:

$\overline{\Delta CH4_t}$	Estimated average methane emission reduction in year *t*; t CO_2e/unit area
$\overline{\Delta CH4\_soil_t}$	Estimated average methane emission reductions from soil organic carbon pool in year *t*; t CO_2e/unit area
$\overline{\Delta CH4\_ent_t}$	Estimated average methane emission reductions from livestock enteric fermentation in year *t*; t CO_2e/unit area
$\overline{\Delta CH4\_md_t}$	Estimated average methane emission reductions from manure deposition in year *t*; t CO_2e/unit area
$\overline{\Delta CH4\_bb_t}$	Estimated 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 34

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

Where:

$\Delta CH4\_soil_{i,t}$	Methane emission reductions from soil organic carbon pool for sample unit *i* in year *t*; t CO_2e
$CH4\_soil_{bsl,i,t}$	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 35

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

Where:

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

Methane emission reductions from manure deposition are quantified as:

Equation 36

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

Where:

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

Methane emission reductions from biomass burning are quantified as:

Equation 37

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

Where:

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

i Sample unit

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

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

Nitrous oxide emission reductions are quantified as:

Equation 38

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

Where:

$\overline{\Delta N2O_t}$	Average nitrous oxide emission reductions in year *t*; t CO_2e/unit area
$\overline{\Delta N2O\_soil_t}$	Average nitrous oxide emission reductions from nitrification/denitrification in year *t*; t CO_2e/unit area
$\overline{\Delta N2O\_bb_t}$	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 39

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

Where:

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

Nitrous oxide emission reductions from biomass burning are quantified as:

Equation 40

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

Where:

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

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

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

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 structural (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_t.

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 statistically robust 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 41

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

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, 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 equation 41); (t CO2e/unit area)^2

$\overline{\Delta CO2_t}$ Estimated average carbon dioxide emission reductions in year *t*; t CO_2e/unit area

$\overline{\Delta CH4_t}$ Estimated average methane emission reductions in year *t*; t CO_2e/unit area

$\overline{\Delta N2O_t}$ Estimated 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.

Quantification Approach 1

Model structural error. Model structural (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 42

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

Where:

$s_{struct,\Delta\bullet,t}$	(Approximate) standard error in $\Delta\bullet$ ($\Delta\bullet$ = emission reductions in gas and pool •) due to model structural uncertainty 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 structural 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 Box 4.1).

If the amount of data for quantifying model structural uncertainty varies significantly among crops, soil texture, and climate zones (see Box 4.1), then a structural model uncertainty 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 structural model uncertainty can be assigned to each sample point i: $s_{\mathrm{struct},\Delta\bullet,i,t}$. Then $s^2_{\mathrm{struct},\Delta\bullet,t}$ 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 2 (Section 8.2) and 3 (Section 8.3)].

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 43

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

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 44

$$\overline{\Delta\bullet_t} = \frac{1}{n}\sum_{i=1}^{n}\overline{\Delta\bullet_{i,t}} = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{m_i}\sum_{j=1}^{m_i}\Delta\bullet_{i,j,t}$$

Where

$\overline{\Delta\bullet_{i,t}}$	Estimated emissions reduction of gas or pool • in year t in field *i*, computed as the average across the sample points in field *i*, $(1/m_i)\sum_{j=1}^{m_i}\Delta\bullet_{i,j,t}$; t CO_2e/unit area

$\Delta \bullet_{i,j,t}$ — Estimated emissions reduction of gas or pool • in year t in field *i,* tile *j* (summed across the whole reporting period for field *i*, tile *j in year t*)*;* t CO_2e/unit area

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

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 45

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

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 (44) simplifies to an average across all measurements, $\overline{\Delta \bullet_t} = \frac{1}{n\,m}\sum_{i=1}^{n}\sum_{j=1}^{m}\Delta \bullet_{i,j,t}$ where $\Delta \bullet_{i,j,t}$ is the estimated emissions reduction of gas/pool • at point *j* 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 46

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

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

Quantification Approach 2

For quantification approach 2, where models are not employed and the baseline scenario is 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 47

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

Where:

$\sigma_{\Delta \bullet t}$	Standard error of the estimate of $\overline{\Delta \bullet} t$. ($\overline{\Delta \bullet} t$ = mean emission reductions from gas and pool • at time *t*); t CO2e/unit area
$s^2_{\bullet,wp,t}$	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
•	Gas or pool

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 9.1

Sources of information for all un-defined activity/management related model input variables (see Table 6.1 and 8.3) and parameters $FFC_{bsl,j,i,t}$, $P_{bsl,l,i,t}$, $Days_{bsl,l,i,t}$, $M_{bsl,SF,i,t}$, $M_{bsl,OF,i,t}$, $H_{bsl,l,i,t}$, 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:

a) 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).

b) 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.

c) 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.

d) Regional (sub-national) average values derived from agricultural census data or other sources from within the 10-year period preceding the project start date, 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	A_0
Data unit	Unit area
Description	Project area
Equations	43
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 project emissions

Comments	None

Data / Parameter:	$VarA_{bsl,i,}$, $VarB_{bsl,i,}$, $VarC_{bsl,i,}$ etc.
Data unit:	Units unspecified
Description:	Value of model input variable A, B, C, etc. in the project scenario for sample unit *i* at time t
Equations	1,4,9
Source of data:	See Box 9.1
Description of measurement methods and procedures to be applied:	See Box 9.1
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 9.1
Purpose of data:	Calculation of baseline emissions
Calculation method:	Not applicable
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	3
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_2 per liter. For diesel EF_{CO2}=0.002886 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. 2004. Energy Statistics Manual).

Data / Parameter	$FFC_{bsl,j,i,t}$
Data unit	Liters/yr
Description	Consumption of fossil fuel type *j* (gasoline or diesel) for sample unit *i* in year *t*
Equations	3
Source of data	See Box 9.1
Value applied	See Box 9.1
Justification of choice of data or description of measurement methods and procedures 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 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	4,5,6,8

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	5
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	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 10.14 and Table 10.15
Value applied	The emission factor is selected from the 2019 Refinement to IPCC 2006 Volume 4 Chapter 10 Table 10.14 and Table 10.15based 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	$VS_{rate,l}$
Data unit	kg volatile solids/(1000 kg animal mass * day)
Description	Default volatile solids excretion rate for livestock type l
Equations	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 10.13a
Value applied	The volatile solids excretion rate is determined 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	CF_c
Data unit	Proportion of pre-fire fuel biomass consumed
Description	Combustion factor for agricultural residue type *c*
Equations	8,26
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 measurement methods and procedures applied	See source of data above
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$EF_{c,CH4}$
Data unit	g CH_4/kg dry matter burnt
Description	Methane emission factor for the burning of agricultural residue type *c*
Equations	8
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	12,16,17,18,21,24,25,26
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	12,18
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.1
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	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	16
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3
Value applied	0.1
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 that volatilizes as NH_3 and NO_x
Equations	16
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3
Value applied	0.3
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	16,24
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 that is lost through leaching and runoff, in regions where leaching and runoff occurs
Equations	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	0.3
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_{Nleach}
Data unit	t N_2O-N / t N leached and runoff
Description	Emission factor for nitrous oxide emissions from leaching and runoff
Equations	17,25
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3
Value applied	0.0075
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	21
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 Table 10.21
Value applied	The emission factor for nitrous oxide from manure and urine deposited on soils is determined 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	Nex_l
Data unit	kg N deposited/(t livestock mass * day)
Description	Nitrogen excretion of livestock type *l*
Equations	22
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
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	$Frac_{GASMD,}$
Data unit	Dimensionless
Description	Fraction of N in manure and urine deposited on soils that volatilizes as NH_3 and NO_x
Equations	24
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 Table 10.22
Value applied	The fraction of N in manure and urine deposited on soils that volatilizes as NH_3 and NO_x is determined 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	$Frac_{LEACHMD}$
Data unit	Dimensionless
Description	Fraction of N in manure and urine deposited on soils that is lost through leaching and runoff, in regions where leaching and runoff occurs
Equations	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	0.30
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	19
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	See source of data above

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

Data / Parameter	$EF_{c,N2O}$
Data unit	g N_2O/kg dry matter burnt
Description	Nitrous oxide emission factor for the burning of agricultural residue type *c*
Equations	26
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	5,6,22
Source of data	See Box 9.1
Value applied	See Box 9.1
Justification of choice of data or description of	See Box 9.1

measurement methods and procedures applied	
Purpose of Data	Calculation of baseline and project 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	5,22
Source of data	See Box 9.1
Value applied	See Box 9.1
Justification of choice of data or description of measurement methods and procedures applied	See Box 9.1
Purpose of Data	Calculation of baseline and project 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	8,26
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	It is assumed that 100% of aboveground biomass is burned in both the baseline and with project cases.

measurement methods and procedures applied	
Purpose of Data	Calculation of baseline and project 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	13
Source of data	See Box 9.1
Value applied	See Box 9.1
Justification of choice of data or description of measurement methods and procedures applied	See Box 9.1
Purpose of Data	Calculation of baseline and project 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	13
Source of data	See Box 9.1
Value applied	See Box 9.1
Justification of choice of data or description of	N content is determined following fertilizer manufacturer's specifications

measurement methods and procedures applied	
Purpose of Data	Calculation of baseline and project 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	14
Source of data	See Box 9.1
Value applied	See Box 9.1
Justification of choice of data or description of measurement methods and procedures applied	See Box 9.1
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	14
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.
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 and project emissions
Comments	None

Data / Parameter	$W_{bsl,l,i,t}$
Data unit	kg lanimal mass/head
Description	Average weight in the baseline scenario of livestock type *l* for sample unit *i* in year *t*
Equations	7,22
Source of data	Peer-reviewed published data or Professional Agronomist judgement may be used
Value applied	See source of data
Justification of choice of data or description of measurement methods and procedures applied	Data from the peer-reviewed scientific literature or expert judgement that are specific to the project area.
Purpose of Data	Calculation of baseline and project emissions
Comments	None

Data / Parameter	$H_{bsl,l,i,t}$
Data unit	Hours
Description	Average grazing hours per day in the baseline scenario for livestock type *l* in sample unit *i* in year *t*
Equations	22
Source of data	See Box 9.1
Value applied	See Box 9.1

Justification of choice of data or description of measurement methods and procedures applied	See Box 9.1
Purpose of Data	Calculation of baseline and project 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	19
Source of data	See Box 9.1
Value applied	See Box 9.1
Justification of choice of data or description of measurement methods and procedures applied	See Box 9.1
Purpose of Data	Calculation of baseline and project 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.

9.2 Data and Parameters Monitored

Data / Parameter:	A_i
Data unit:	Unit area
Description:	Area of sample unit *i*
Equations	4,9,43

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:	$VarA_{wp,I}$, $VarB_{wp,I}$, $VarC_{wp,I}$, etc.,
Data unit:	Dimensionless
Description:	Value of model input variable A, B, C etc. in the project scenario for sample unit *i* at time t
Equations	1,4,9
Source of data:	See Box 9.1
Description of measurement methods and procedures to be applied:	See Box 9.1
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 9.1

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:	*i*
Data unit:	Dimensionless
Description:	Sample unit; defined area that is selected for measurement and monitoring, such as a field
Equations	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23, 24,25,26,30,31,32,34,35,36,37,39,40
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	2,3
Source of data:	Determined in sample unit *i*
Description of measurement methods and procedures to be applied:	See Box 9.1. Fossil fuel 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 9.1.
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	5,6,7,21,22
Source of data:	Determined in sample unit *i*
Description of measurement methods and procedures to be applied:	See Box 9.1. 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 9.1.
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	19
Source of data:	Determined in sample unit *i*
Description of measurement methods and procedures to be applied:	See Box 9.1. 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 9.1.
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	8,26
Source of data:	Determined in sample unit *i*
Description of measurement methods	See Box 9.1. Agricultural residue 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 9.1.
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	38,39,40,41,42
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:	$SOC_{bsl,i,t}$

Data unit:	t CO_2e/unit area
Description:	Areal-average stock of soil organic carbon in the baseline scenario for sample unit *i* at the end of year *t*
Equations:	30
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: $SOC\_soil_{bsl,i,t}$ = 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) $Var\ A_{bsl,i,t}$ = 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)
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 or from the IPCC GPG LULUCF 2003 is recommended.
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.

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	30,31
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: $$SOC_{wp,i,t} = f_{SOC}(Var\ A_{bsl,i,t}, Var\ B_{bsl,i,t}, \ldots)$$ Where: $SOC\_soil_{wp,i,t}$ = 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) Measured soil organic carbon must be determined from samples collected from sample plots located within each sample unit. Soil must be sampled to a minimum depth of 30 cm. 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.
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 or from the IPCC GPG LULUCF 2003 is recommended.
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.

Data / Parameter:	$\Delta SOC_{bsl,i.t}$
Data unit:	t CO_2e
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
Equations	31
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
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:	None

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	27,28,29,31,36
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:	$\Delta C_{TREE,bsli,t}$
Data unit:	t CO_2e
Description:	Change in carbon stocks in trees in the baseline w
Equations	29
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 and project 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
Description:	Change in carbon stocks in shrubs in the baseline w
Equations	29
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 and 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/yr
Description:	Consumption of fossil fuel type *j* for sample unit *i* in year *t*
Equations	3
Source of data:	See Box 9.1
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 baseline scenario of type *l* in sample unit *i* in year *t*
Equations	5,6,22
Source of data:	See Box 9.1

Description of measurement methods and procedures to be applied:	Record numbers of grazing livestock 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 *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 baseline scenario inside sample unit *i* for each livestock type *l* in year *t*
Equations	5,22
Source of data:	See Box 9.1
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 baseline scenario for sample unit *i* in year *t*
Equations	8,26
Source of data:	See Box 9.1
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 baseline N containing synthetic fertilizer applied for sample unit *i* in year *t*
Equations	13
Source of data:	See Box 9.1
Description of measurement methods and procedures to be applied:	See Box 9.1
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 baseline N containing organic fertilizer applied for sample unit *i* in year *t*
Equations	14

Source of data:	See Box 9.1
Description of measurement methods and procedures to be applied:	See Box 9.1
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 baseline scenario of livestock type *l* for sample unit *i* in year *t*
Equations	7,22
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:	$H_{wp,l,i,t}$
Data unit:	Hours
Description:	Average grazing hours per day in the baseline scenario for livestock type *l* in sample unit *i* in year *t*
Equations	22
Source of data:	See Box 9.1
Description of measurement methods and procedures to be applied:	Record the average number of grazing hours per day during grazing season in year *t*
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:	None

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	19
Source of data:	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	27,28
Source of data:	Not applicable
Description of measurement methods and procedures to be applied:	Leakage is equal to zero per the applicability conditions 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

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

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 unbiased 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).

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 structural uncertainty. 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