Verified Carbon Standard

VCS Methodology

VM0051

IMPROVED MANAGEMENT IN RICE PRODUCTION SYSTEMS

Version 1.0

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Sectoral Scope 14: AFOLU

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CONTENTS

1 SUMMARY DESCRIPTION

Table 1. Additionality, crediting baseline, and mitigation outcome

Additionality, Crediting Method, and Mitigation Outcome	
Additionality	Project Method
Crediting Baseline	Project Method
Mitigation Outcome	Reductions

This agricultural land management (ALM) methodology provides procedures to estimate the greenhouse gas (GHG) emission reductions (CH_4, N_2O, and CO_2) resulting from the adoption of improved management practices in rice production systems.

The methodology is compatible with sustainable agriculture and has a particular focus on reducing methane (CH_4) emissions from the cultivation of rice. Practices that are expected to result in material declines in soil organic carbon (SOC) are not eligible under this methodology. Projects that seek credits for SOC stock increases (removals) or that employ practices that result in material declines in SOC must use VCS methodology *VM0042 Improved Agricultural Land Management*.

The crediting baseline and additionality are determined via a project method (Table 1). The baseline scenario assumes the continuation of pre-project rice cultivation practices. The management practices in the baseline scenario are determined by applying a historical look-back period to produce an annual schedule of activities (i.e., irrigation and water regime, planting date and type, fertilization practices, drainage event(s), harvest dates, and off-season practices) for each quantification unit (e.g., for each field) within the project area, over the project crediting period.[1]

Each project must include activities that materially reduce soil methanogenesis (reducing CH_4 emissions) and may optionally include further practices, including avoided biomass burning (reducing CH_4 and N_2O emissions), application of biochar, use of methanotrophs, improved nitrogen fertilizer management (i.e., reductions in total nitrogen usage and/or the use of interventions such as nitrification inhibitors), and more efficient fossil fuel usage (reducing CO_2

[1] At crediting period renewal, the validity of the original baseline scenario must be reassessed. Where the original baseline is determined to be invalid, a new baseline scenario reflecting current rice production practices in the region must be developed. For more details, see the most recent rules on baseline reassessment and project crediting renewal in Sections 3.2.7 and 3.9.8 of the *VCS Standard, v4.7* or equivalent sections of the most recent version.

emissions). Any quantitative adjustment in optional practices must exceed 5% of the pre-existing value to qualify as a practice change.

Additionality is demonstrated by a regulatory surplus assessment, barrier and/or investment analysis, and a common practice test to determine that the practice change implemented under the project activity is not common practice.

Reductions are quantified using one of three eligible quantification approaches (QAs), including QA1: using a biogeochemical, process-based model; QA2: direct measurements of CH_4 emissions; and QA3: default equations and emission factors. Available options differ depending on the GHG pool or source being assessed and the scale of the project. Simplified procedures are provided for projects using Quantification Approach 3 that have a capacity limit of 60 000 t CO_2e per year. See Table 4 for a summary of allowable quantification options and Section 8.1 for the details of each approach.

2 SOURCES

This methodology is based on the following methodologies:

- *VM0042 Improved Agricultural Land Management, v2.1*
- Clean Development Mechanism (CDM) *AMS-III.AU Methane Emission Reduction by Adjusted Water Management Practice in Rice Cultivation, v04.0*
- Joint Crediting Mechanism (JCM) *PH_AM004 Methane Emission Reduction by Water Management in Rice Paddy Fields*, *v01.0*
- Gold Standard *Methodology for Methane Emission Reduction by Adjusted Water Management Practice in Rice Cultivation, v1.0*

This methodology uses the most recent versions of the following tools, modules, and guidelines:

- *VMD0053 Model Calibration, Validation, and Uncertainty Guidance for the Methodology for Improved Agricultural Land Management*
- *VT0008 Additionality Assessment*
- *CDM Tool for Testing Significance of GHG Emissions in A/R CDM Project Activities*
- *CDM TOOL16 Project and Leakage Emissions from Biomass*
- *CDM EB67 A06 Guideline: Sampling and Surveys for CDM Project Activities and Programmes of Activities*

3 DEFINITIONS

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

Alternate wetting and drying (AWD)
A system of cultivating irrigated lowland rice using controlled and intermittent irrigation cycles according to a periodic drainage and re-flooding schedule (i.e., alternating flooded and non-flooded field conditions by multiple (more than one) drainage events during the cultivation period) in addition to end-of-season drainage. This water management technique uses less water than the usual system of continuously flooded irrigation in the crop field.

Avoided biomass burning
Residue management system in which residue (i.e., rice straw) is not burned after harvest

Baseline control site
Defined area that is managed according to pre-project (baseline) practices (as set out in the schedule of activities) for direct measurement of CH_4 using flux chambers and that is representative of the land and management practices in one or more quantification units

Continuous flooding

A system of cultivating irrigated lowland rice where fields have standing water throughout the rice growing season and are drained only shortly before the maturing growth stage and for harvesting the rice (i.e., end-of-season drainage)

Controlled irrigation
A type of water management where the project has irrigation systems in place that allow for controlled management of the water regime (i.e., the project farmer has control of the water flow rate, flooding duration, etc.)

Cultivation pattern

The set of activities and machinery operations used to cultivate rice in the project area. This requires describing quantitative and qualitative details related to the implementation of the project activities and management practices (e.g., time, duration, rate, and frequency of wet (flooded) and dry (non-flooded) periods, machinery operations, fertilization practices, and weed and pest control)

Cultivation period
The period of time that begins with pre-planting preparation in rice fields and ends at the harvest event

Direct seeded rice (DSR)

A system of cultivating irrigated lowland rice in which seeds, either pre-germinated or dry, are broadcast or sown directly in the field under dry or wetland conditions. No transplanting process is involved. DSR reduces the duration of flooding periods compared to transplanted rice with continuous flooding. For DSR, the field must be dry before seeding and remain dry during sowing until the seed has germinated so that viable, young plantlets can withstand shallow flooding (at the two–four leaf stage).

Digital monitoring, reporting, and verification (DMRV) tools

Tools used to enable digital capture, analysis, tracking, and dissemination of data to enable monitoring, reporting, and verification

Historical look-back period

The time period prior to the project start date covering at least three years of rice cultivation and a complete crop rotation, if any. The historical look-back period is used to produce the schedule of activities.

Liming

The application of calcium- and magnesium-rich materials such as lime or limestone to soil to neutralize soil acidity

Methanotrophs

Organisms that occur naturally or are introduced to an environment and metabolize CH_4 to obtain their energy, thereby removing CH_4 from their environment

Quantification unit

The unit below the project level and the unit at which GHG emission reductions and carbon dioxide removals and associated uncertainty are estimated using the selected quantification approach. Depending on the sampling design, the quantification unit may be a stratum, a cluster of fields, or another unit or group of units.

Sample unit

Unit at which measurements are taken during gas sampling under Quantification Approach 2

Scaling factor

A numerical multiplier that is applied to an emission factor to align it with observed data from specific national or regional conditions. It is used to minimize biases, refine calculations, or downscale global emission factors.

Schedule of activities

An annual schedule of historical management activities (e.g., irrigation, fertilizer usage, and biomass amendments) applied in the baseline and derived from the historical look-back period. The schedule is determined following the data requirements given in Box 1.

Single drainage
A system of cultivating irrigated lowland rice using a controlled and intermittent irrigation cycle (i.e., fields have a single drainage event and period during the cropping season at any growth stage) in addition to the end-of-season drainage

Soil methanogenesis
Microbial process that produces methane (CH_4) gas in soils when microorganisms break down organic matter under anoxic conditions, such as in waterlogged soils

Stratification
The act of dividing the project area into relatively homogeneous strata. Stratification can occur at the project level and within a quantification unit.

Stratum
A discrete area in which biophysical factors are more homogeneous than they are across the project area as a whole

Water regime
The water management system used within a rice production system (i.e., the irrigation method)

4 APPLICABILITY CONDITIONS

This methodology applies to improved rice cultivation practices that decrease net emissions of CH_4, N_2O, and/or CO_2. The methodology is globally applicable.

This methodology is applicable under the following conditions:

1) Projects implement improved irrigation management practices that result in CH_4 emission reductions from methanogenesis (i.e., “main project activities”), including at least one of the following:

    a) Single drainage and/or a shortened period of flooded condition

    b) Alternate wetting and drying (AWD)

    c) Use of direct seeded rice (DSR)

Note – Projects may implement additional activities to further reduce CH_4 emissions and/or reduce N_2O and/or CO_2 emissions (i.e., “optional project activities”), including use of methanotrophs, introduction of short-duration or low-emission rice cultivars where project proponents ensure no material changes in carbon inputs to the system through root biomass, avoided biomass burning (of rice residues), reductions in fossil fuel use, improvements in nitrogen management (i.e., reduction in total nitrogen applied and/or the use of nitrification inhibitors or slow-release nitrogen fertilizers), and application of biochar to soils.

2) Projects introducing or implementing quantitative adjustments (e.g., decrease in fertilizer application rate or fossil fuel use) exceed 5% of the pre-existing value calculated as the average value over the historical look-back period, developed for the baseline schedule of activities (see Section 6).

3) The project rice fields are equipped with controlled irrigation and drainage facilities, such that appropriate flooded/non-flooded soil conditions can be established and desired emission reductions can be achieved.

4) The introduced project activities are not subject to any local regulatory restrictions as per the most recent requirements of the *VCS Standard*.

5) The project area has not been cleared of native ecosystems within the 10 years immediately preceding the project start date.

6) The project fields maintain the same number of rice cultivation periods per year as in the historical look-back period (e.g., no shift from three to two growing seasons).

This methodology is not applicable under the following conditions:

7) Practices are introduced that result in material declines in SOC stocks due to declines in the carbon input rate to soils (e.g., increased rice straw removal, decreased application rate of manure or compost, and introduction of new cultivars known to have a materially smaller root system than the cultivar(s) used in the baseline)[2]

8) Rice is grown under upland,[3] rainfed or deep-water,[4] or non-irrigated lowland rice production systems.

9) Projects change off-season (i.e., outside of the rice cultivation period) management practices (e.g., fertilizer application rates, tillage, crop rotations and crop types, and/or deviation of livestock management from historical off-season management practices). The following exceptions apply:

    a) Avoided crop residue burning after harvest (during the off-season)

    b) Reducing the flooding period prior to the start of the cultivation period only on fields that have no crop rotations (i.e., fields exclusively dedicated to flooded rice production)

[2] Projects that seek credits for SOC stock increases or employ practices that may result in material declines in SOC must use *VM0042*.

[3] A type of water regime in which fields have well-drained soils without surface water accumulation and are never flooded for a significant period of time

[4] A type of water regime in which fields are flooded for a significant period of time and water inputs depend solely on precipitation with no controlled irrigation systems

10) Projects seek to credit CO_2 removals due to the use of biochar.[5]

5 PROJECT BOUNDARY

The spatial extent of the project boundary is all lands on which the proposed rice cultivation activities will be implemented.

GHG sources included in the project boundary in the baseline and project scenario are listed in Table 2 below.

Table 2. GHG sources included in or excluded from the baseline and project scenarios

Source	GHG	Included?	Justification/Explanation
Soil methanogenesis	CH_4	Yes	Changes in levels of anoxic conditions in soils lead to significant changes in soil methanogenesis. This is the dominant GHG source under this methodology.
Fossil fuels	CO_2	S*	Where there are changes in the use of equipment such as tractors, seeders, harvesters, or irrigation pumps, these changes may result in material increases or decreases in CO_2 emissions associated with the combustion of fossil fuels.
Liming	CO_2	S*	Application of limestone or dolomite for soil amelioration may represent a significant source of CO_2.
Enteric fermentation	CH_4	No	Projects that are expected to result in material changes in livestock management are not eligible under this methodology. Projects that seek credits for livestock management changes should use *VM0042*.
Manure deposition	N_2O CH_4	No	Projects that are expected to result in material changes in livestock management are not eligible under this methodology. Projects that seek credits for livestock management changes should use *VM0042*.
Use of nitrogen fertilizers and nitrogen derived from crop residue (i.e., rice straw) incorporated into soils	N_2O	Yes	N_2O attributed to changes in irrigation must be included in all projects.
		S*	Where nitrogen fertilization rate and/or nitrogen returned to soils from crop residues is greater in the monitoring period than the baseline scenario, such N_2O emissions must be included in the project boundary.
Biomass burning	CH_4	S*	Biomass burning releases CH_4.

[5] Projects that seek credits for CO_2 removals due to use of biochar should use *VM0044 Methodology for Biochar Utilization in Soil and Non-Soil Applications*.

	N_2O	S*	Biomass burning releases N_2O.

S* – Must be included where the project activity significantly increases total GHG emissions by more than 5% compared to the baseline scenario (i.e., emissions are not de minimis) and may be included where the project activity reduces total GHG emissions by more than 5% compared to the baseline scenario.

6 BASELINE SCENARIO

This methodology considers multiple baseline scenarios, all of which are founded on an assessment of pre-project rice management practices, in particular on-season water regime management. For each project field, the baseline scenario is derived from practices implemented in the (minimum three-year) historical look-back period, creating an annual schedule of activities to be repeated throughout the baseline scenario and used to estimate baseline emissions and net project emission reductions during each monitoring period. Baseline emissions are modeled (QA1), directly measured for soil methanogenesis only (QA2), and/or estimated using default emission factors (QA3).

The practices assumed in the baseline scenario must be reassessed at the end of a project crediting period (i.e., when applying for project crediting period renewal) to ensure that they reflect the current rice production system in the region.

Development of Schedule of Activities in the Baseline Scenario

For each project field, a schedule of activities in the baseline scenario is determined by assessment of historical 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 three years and must include at least one complete crop rotation, where applicable. Where a crop rotation is not implemented in the baseline, $x \geq 3$ years. To develop the schedule of activities, project proponents must refer to Table 3 to collect data on all cropping management-related parameters (as defined in the "ALM practices" column) for each project field and for each year from $t = -1$ to $t = -x$ (i.e., years preceding project start) of the historical look-back period. In addition, project proponents must collect data on machinery operations and liming applications (i.e., type, rates, and timing). In most cases, quantitative information is associated with related qualitative information (see Box 1 for guidance on and a hierarchy of data sources). Thus, a negative response to a qualitative element would mean there is no quantitative information related to that practice, whereas a positive response to a qualitative element requires quantitative information related to that practice.

The schedule of activities, beginning with year $t = -x$, is applied in the baseline scenario from $t = 1$ onward, repeating every *x* years through the end of the first baseline period. At the end of each baseline period, production of the commercial crop (i.e., rice) in the baseline scenario is re-evaluated. Published regional (sub-national) agricultural production data from within the five years immediately preceding the end of the current baseline period must be consulted. The schedule of activities in the baseline scenario is valid until re-assessment is required.

Table 3. Minimum specifications for the identification of agricultural land management (ALM) practices in rice production systems in the baseline scenario

ALM practices	Qualitative	Quantitative
Water regime (pre- and on-season)	• Irrigation (Y/N) • Flooding on-season (Continuous/Single/Multiple) • Flooding pre-season (Flooded/Short- or Long-drainage)	• Irrigation rate/volume • Flooding duration (days) • Water level (below surface)
Crop planting and harvesting	• Crop type(s) • Rice variety • Rice seeding practice (DSR/Transplanting)	• Approximate date(s) of seeding • Approximate date(s) harvested/terminated • Crop yield
Tillage and/or residue management	• Tillage (Y/N) • Crop residue removal (Y/N) • Crop residue incorporation (Y/N) • Burning crop residue (Y/N) • Usage of non-burned crop residue (final end-use type)	• Tillage depth (where applicable) • Tillage frequency (where applicable) • Tillage area (where applicable) • Crop residue rate left in situ (where applicable) • Crop residue incorporation timing (where applicable) • Burned area (where applicable)
Nitrogen fertilizer application	• Organic amendment (Y/N) • Organic amendment type(s) • Synthetic N fertilizer (Y/N) • Synthetic N fertilizer type(s)	• Organic amendment type application rate (where applicable) • Synthetic fertilizer type application rate (where applicable)
Other amendments	• Biochar (Y/N) • Methanotrophs (Y/N)	• Biochar application rate (where applicable) • Methanotroph application rate (where applicable)
Liming	• Application of calcitic limestone or dolomite (Y/N)	• Calcitic limestone or dolomite application (where applicable) • Approximate date(s) of calcitic limestone or dolomite application (where applicable)
Machinery and equipment operations	• Fossil fuel usage (Y/N) • Fossil fuel type(s)	• Fossil fuel type rate (where applicable)

*Y/N: Yes/No

This may result in a baseline scenario of a continuously flooded on-season water regime (with associated management practices, e.g., N fertilizer management and organic amendment applications) and the length of flooding conditions pre-season, since this methodology targets the transition from continuous flooding to single drainage, and/or the shortened period of flooding conditions pre-season, AWD, and/or DSR to reduce CH_4 emissions from soil methanogenesis. However, where the on-season water regime includes single drainage during the historical look-back period, project proponents must conservatively set single-season drainage as the on-season water regime for the entirety of the baseline scenario for those project fields (i.e., even where there is just one year of single-season drainage during the minimum three-year historical look-back period, the schedule of activities for on-season water regime must include annual single-season drainage). This represents an alternative baseline scenario and is a more conservative approach to baseline setting because it requires projects to assume that single-season drainage (which has lower CH_4 emissions than continuous flooding) would have happened every year of the baseline scenario. Further, in fields where the alternative baseline scenario is used, projects must implement the shortened period of flooding conditions prior to the start of the cultivation period, multiple drainage events, and/or DSR.[6]

Last, in circumstances where actual weather conditions during the monitoring period result in a cultivation period with a longer duration than the baseline scenario cultivation period (as derived from the schedule of activities), project proponents may set the baseline scenario cultivation period equal to the project scenario cultivation period for affected fields during the same season of the monitoring period. To qualify for this exception, project proponents must demonstrate that the duration of the project scenario cultivation period (from pre-planting to harvesting) is commensurate with non-project fields by using data from reference fields in the same region as the project area[7] or providing other evidence following the data sourcing hierarchy in Box 1.

Box 1. Sources of qualitative and quantitative data

Sources of information for all activity/management-related variables and all parameters relevant to the baseline must follow the requirements detailed below.

All qualitative information on ALM practices must be determined via consultation with the farmer or landowner. Where the farmer or landowner is not able to provide qualitative information (e.g., a field is newly leased), the project proponent must follow the quantitative information hierarchy outlined below.

[6] This ensures that greater CH_4 reductions are achieved than would have occurred where implementing solely single-season drainage in the project scenario.

[7] This ensures that baseline conditions are dynamic and project proponents are not unduly penalized for changes in weather conditions that are outside of their control.

The following list specifies the allowable sources of quantitative information on ALM practices in descending order of preference, as available:

1) Historical management records supported by one or more forms of documented evidence pertaining to the selected field and period $t = -1$ to $t = -x$ (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 ALM practices can be reliably determined with these methods (e.g., irrigation patterns before and during the cultivation period, type and amount of synthetic N fertilizers and organic amendments, and the duration of the cultivation period)

2) Historical management plans supported by one or more forms of documented evidence pertaining to the selected field and period $t = -1$ to $t = -x$ (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 conservativeness must be applied and the value that results in the lowest expected emissions in the baseline scenario must be selected.

3) A signed attestation from the farmer or landowner where 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 on application rates in that area, or statement from a local extension agent regarding local application rates). Digital technologies may be used to generate farmer attestations. For example, where an application is used to present information to a farmer and to digitally record their acceptance of the information as accurately reflecting their cultivation practices, such a digital record is considered a farmer attestation. The validation/verification body (VVB) must determine whether the data are sufficient. In circumstances where this requirement is not met, the source listed in 4) below must be used.

4) Regional (sub-national) average values derived from agricultural census data or other sources from within the 20-year period preceding the project start date or the 10 most recent iterations of the dataset, whichever is more recent. Where estimates have been disaggregated by ownership classes, those should be used. The estimates must be substantiated with a signed attestation from the farmer or landowner of the 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.

This hierarchy applies to any quantitative inputs required by the model (QA1), direct measurements (QA2), and default factors (QA3). The principle of conservativeness must be applied in all cases.

7 ADDITIONALITY

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

7.1 Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements set out in the most recent versions of the *VCS Standard* and *VCS Methodology Requirements*.

Where the project proponent demonstrates regulatory surplus, proceed to Section 7.2 (barrier analysis and/or investment analysis). Otherwise, the project activity is not additional.

7.2 Barrier Analysis and/or Investment Analysis

Project proponents must follow the procedures and requirements of the most recent version of VCS tool *VT0008 Additionality Assessment* to conduct either a barrier analysis (Step 2) or an investment analysis (Step 3). Project proponents may choose to apply both analyses to further strengthen the additionality demonstration.

Project proponents implementing multiple project activities may conduct the barrier analysis and/or investment analysis across the suite of activities.

Where the project proponent demonstrates that all conditions of either the barrier analysis or the investment analysis per *VT0008* are met, proceed to Section 7.3 (common practice analysis). Otherwise, the project activity is not additional.

7.3 Common Practice Analysis

The project proponent must determine whether each proposed project activity is common practice in each region included within the project spatial boundary. To be eligible, each main project activity[8] and any optional project activities[9] included in the project must not be common practice (i.e., must not have a penetration rate greater than 20% adoption[10]).

Project proponents must use the historical look-back period as set out in Section 6 to determine regional common practice.

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[8] Main project activities are exclusively those that improve irrigation management practices resulting in CH_4 emission reductions from methanogenesis; see Applicability Condition 1 in Section 4.

[9] Optional project activities are management practices that further reduce CH_4 emissions and/or that reduce N_2O and/or CO_2 emissions.

[10] The precedent for a common practice threshold of greater than 20% is established in Section 5.5.3 of *VT0008 Additionality Assessment, v1.0*.

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

1) agricultural census or other government (e.g., survey) data;
2) peer-reviewed scientific literature;
3) independent research data;
4) attestation statement from a qualified independent local expert (e.g., accredited agronomists affiliated with official agricultural institutions supporting rice production such as the International Rice Research Institute, IRRI);
5) grower surveys conducted within the project region;
6) reports or assessments compiled by industry associations; or
7) data compiled using remote sensing datasets.

To demonstrate common practice, the project area must be stratified to the state or provincial level (or equivalent second-order jurisdiction) in the countries where the project is being developed. Where supporting evidence is unavailable at the state/provincial level (e.g., in developing countries), aggregated data or evidence at a national or regional level may be used with justification. Where stratification based on geopolitical boundaries is impractical (e.g., due to lack of data), other forms of stratification, such as major soil types or cropping zones (i.e., dominant production system defined by regional or local climatic conditions), may be used with justification. The same stratification approach and data sources must be applied across the entire project to maintain the integrity of the common practice demonstration. Where a data source is unavailable for a subset of the project region, justification must be provided for use of a different data source.

When conducting the common practice analysis, activities that are under validation or registered under the VCS Program are excluded from determining the penetration rate. Activities under other GHG programs may optionally be excluded.[11]

Where the main project activity and optional project activities are not common practice, and the steps of additionality analysis are satisfied, the proposed project activity is additional. Otherwise, the project activity is not additional and is not eligible for crediting.

[11] The precedent for the exclusion of activities registered under the VCS Program and other GHG programs is established in Section 5.5.3 of *VT0008 Additionality Assessment, v1.0*.

8 QUANTIFICATION OF REDUCTIONS AND REMOVALS

8.1 Summary

This methodology provides three approaches to quantify GHG emission reductions from the sources included in the project boundary (Table 2) due to the adoption of improved management practices in rice production. The project proponent must demonstrate that implementing a proposed practice improves the pre-existing practice within the rice production system in the project region.

Baseline and project emissions are defined in terms of flux of CH_4, N_2O, and CO_2 in tonnes of carbon dioxide equivalent (t CO_2e) per unit area per monitoring period. Within each quantification unit, emission changes in each included source are treated on a per unit basis in accounting procedures. Section 8.5 provides equations using total emission changes in the project to quantify net reductions. Where a verification period spans multiple calendar years, the equations quantify reductions by year to appropriately define vintage periods.

The entire project area is divided into multiple quantification units that must be more homogeneous than the project area in its entirety for the purpose of estimating emission reductions (e.g., similar management activities and biophysical conditions; see for further details on defining the cultivation pattern and stratifying the project area).

The allowable approaches for quantifying CH_4, N_2O, and CO_2 emissions by GHG source are listed in Table 4. A project may employ multiple quantification approaches provided that the same approach is used for both the project and baseline scenarios for the given GHG source within the given monitoring period.

Table 4. Summary of quantification approaches

GHG	Source	Quantification Approach 1: Modeling	Quantification Approach 2: Direct Measurement	Quantification Approach 3: Default Emission Factors
CH_4	Soil methanogenesis	X	X	X
CH_4, N_2O	Biomass burning			X
N_2O	Use of nitrogen fertilizers, including nitrogen from rice straw (crop residue)	X		X
CO_2	Fossil fuels			X
CO_2	Liming			X
CO_2	SOC*	X*		

*This methodology does not credit removals (i.e., SOC stock increase). However, where Quantification Approach 1 is used, the SOC pool must be modeled.

Three quantification approaches are available under this methodology, described below.

Quantification Approach 1 (QA1): Modeling of Soil Methanogenesis and Nitrous Oxide Fluxes

An acceptable model is used to estimate GHG flux following the requirements and procedures in *VM0042* and *VMD0053*. The requirements for demonstrating the selection of an acceptable model are detailed in Section 2.5.1 of the *VCS Methodology Requirements*, *v4.4*. It must be demonstrated that the model domain sufficiently covers any potential flux changes in CH_4 (soil methanogenesis) and N_2O (if modeled) associated with the implementation of project activities, including changes in the water regime, cultivation period (duration), fertilization practices, and changes in rice varieties.

Neither initial nor periodic measurements of CH_4 and N_2O fluxes are required as part of project monitoring. High-quality observed experimental data on soil CH_4 and N_2O emissions from controlled research trials or approved data sources as described in *VMD0053* are required for model calibration (see Section 5.1 of *VMD0053, v2.0*) and validation (see Section 5.2.3 of *VMD0053, v2.0*). Measured datasets must be drawn from peer-reviewed and published experimental datasets with measurements of N_2O and CH_4 fluxes, ideally using control plots to test the impact of practice change on GHG fluxes. Datasets may also be drawn from a benchmark database maintained by a third party or from measurements made within the project boundary, where approved by the independent modeling expert (see Appendix 1 of *VMD0053*, *v2.0*).

Other GHG fluxes not covered by the model domain (such as CO_2 due to liming, CO_2 from fossil fuel usage, and avoided biomass burning) must be accounted for using the default emission factor approach (QA3).

Quantification Approach 2 (QA2): Direct Measurement of Soil Methanogenesis

Direct flux chamber measurements are used to quantify flux in CH_4 emissions from soil methanogenesis. This approach is relevant where models are unavailable or have not yet been validated or parameterized, or where project proponents prefer to use a direct measurement approach for CH_4 emissions.

QA2 must be used where the project is implementing any of the following:

1) Use of methanotrophs
2) Application of biochar
3) Planting low-emission rice varieties
4) AWD to a depth of less than 10 cm below the soil level, as recommended by a project expert

QA2 requires establishing baseline control sites which are linked to one or more quantification units to directly measure and remeasure CH_4 emissions in the baseline scenario and project activity. The guidance for directly measuring CH_4 using flux chambers is outlined in Appendix 2. All other GHG fluxes (e.g., N_2O from fertilizers, CO_2 from liming, CO_2 from energy usage, and combustion emissions related to avoided biomass burning) must be accounted for and quantified by using either QA1 or QA3.

Quantification Approach 3 (QA3): Default Emission Factors (Global/Regional/Country-Specific)

Baseline and project emissions are calculated for quantification units using applicable default emission factors. Flux in CH_4 from biomass burning and CO_2 from both fossil fuel usage and liming is calculated using emission factors and guidance in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* with specific equations and additional guidance contained in this methodology. Flux in CH_4 from soils and in N_2O from nitrogen fertilizers or rice straw management may optionally also follow this approach. However, where default emission factors are not available for these sources, one of the other quantification approaches must be used. For N_2O emissions, emission factors for nitrification inhibitors and enhanced efficiency fertilizers may be derived from the literature. The most accurate and geographically specific emission factor applicable to the project must be used from the following (listed in descending order of preference):

1) Where available, a project-specific emission factor from a peer-reviewed scientific publication[12] must be used.
2) Where there is no relevant peer-reviewed scientific literature, the project proponent may propose alternative sources of information (e.g., government databases, industry publications) to establish the default factor(s) and must provide evidence that the

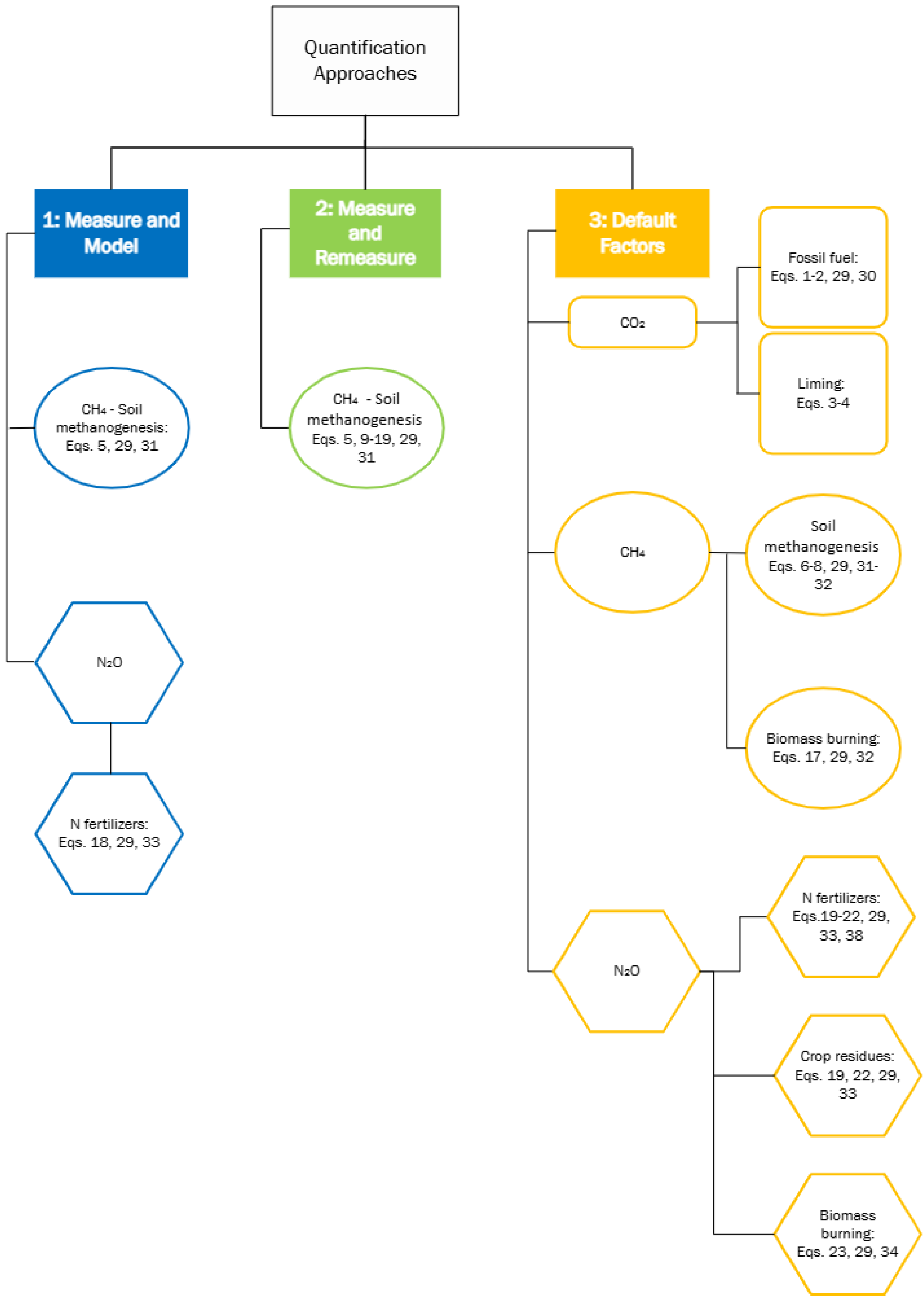
[12] As stated in Section 2.5 of the *VCS Methodology Requirements, v4.4*, peer-reviewed scientific literature used to derive (default) emission factors must be published in a journal indexed in the Web of Science: Science Citation Index.

alternative source of information is robust and credible (e.g., independent expert attestation). This approach must not be used for CH_4 and N_2O from soils.

3) Where no alternative information source is available that is applicable to the project conditions, projects may derive emission factors using peer-reviewed scientific literature following the guidance to derive Tier 2 emission factors in the respective sections of the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*.
4) Where projects have an emission capacity limit[13] equal to or less than 60 000 t CO_2e per year, simplified (e.g., global or regional) Tier 1 emission factors for CH_4 emission from soils from the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* may be used. All other projects must use country-specific emission factors for CH_4 from soils.

[13] See Section 3.6.9 of *VCS Standard, v4.7*.

Figure 1. Equation map of this methodology



8.2 Baseline Emissions

Baseline quantification must be undertaken following the guidance below and in Sections 8.2.1–8.2.7.

Quantification Approach 1 (QA1): Modeling

The baseline emissions are modeled for each quantification unit. The model serves to project future emissions resulting from the schedule of activities in the baseline scenario (derived in Section 6 and Appendix 1). Under QA1, direct measurements of SOC stocks are required as model inputs for model initialization and, at minimum, at every project crediting renewal period.[14] Where the project involves the introduction of a new cultivar with a materially different root biomass from the cultivar(s) used in the baseline, the project proponent must demonstrate that the model domain sufficiently covers such changes. Further guidance on the use of biophysical model inputs is given in Section 8.1 and in *VM0042 and VMD0053*.

Quantification Approach 2 (QA2): Direct Measurement

Under this approach, project proponents must perform direct field chamber measurements of CH_4 fluxes during every cultivation period at baseline control sites and linked quantification units (i.e., at the sample unit). One baseline control site may be linked to more than one quantification unit provided the control site meets the similarity criteria for each quantification unit to which it is linked. Projects must use QA2 for all fields where biochar, methanotrophs, or low-emission rice varieties are being implemented.

Quantification Approach 3 (QA3): Default Emission Factors (Global/Regional/Country-Specific)

Baseline scenario emissions are calculated using the equations provided based on practices established in the schedule of activities (derived in Section 6). These emissions are estimated using default emission factors and data are determined for each field at validation.

8.2.1 Carbon Dioxide Emissions from Fossil Fuel Combustion

Where CO_2 emissions from fossil fuel are included in the project boundary per Table 2, they are quantified in the baseline scenario under Quantification Approach 3, using Equations (1) and (2).

$$\overline{CO_2\_ff_{bsl,i,t}} = (\sum_{j=1}^{J} EFF_{bsl,i,j,t})/A_i \quad (1)$$

14 Initial measurements of SOC may be conducted at t = 0 or (back-) modeled to t = 0 from measurements collected within ±5 years of t = 0. This time frame (5 years) should be shortened where possible. For projects with more than one project crediting period (i.e., more than a 10-year cycle), SOC measurements must be taken for each renewal period. For further guidance on SOC measurement procedures refer to Section 8.2.1 of *VM0042, v2.1* or equivalent section in the most recent version.

Where:

$\overline{CO_2\_ff_{bsl,i,t}}$	=	Areal mean carbon dioxide emissions from fossil fuel combustion for quantification unit *i* in year *t* in the baseline scenario (t CO_2e/ha)
$EFF_{bsl,i,j,t}$	=	Carbon dioxide emissions from combustion of fossil fuel type *j* for quantification unit *i* in year *t* in the baseline scenario (t CO_2e)
A_i	=	Area of quantification unit *i* (ha)
j	=	Type of fossil fuel (gasoline, diesel, or other)

$$EFF_{bsl,i,j,t} = FFC_{bsl,i,j,t} \times EF_{CO2,j} \tag{2}$$

Where:

$FFC_{bsl,i,j,t}$	=	Consumption of fossil fuel type *j* for quantification unit *i* in year *t* in the baseline scenario (L)
$EF_{CO2,j}$	=	Emission factor for combustion of fossil fuel type *j* (t CO_2e/L)

8.2.2 Carbon Dioxide Emissions from Liming

Application of calcitic limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) releases bicarbonate (HCO_3^-), which evolves into CO_2 and water (H_2O) as carbonate limes dissolve. Where one of the rice production practices is liming and resulting CO_2 emissions are not deemed de minimis, emissions are quantified in the baseline scenario using Quantification Approach 3 and Equations (3) and (4) or Quantification Approach 1 where the chosen model includes estimations of CO_2 emissions from liming.

$$\overline{CO2\_lime_{bsl,i,t}} = EL_{bsl,i,t} / A_i \tag{3}$$

Where:

$\overline{CO2\_lime_{bsl,i,t}}$	=	Areal mean carbon dioxide emissions from liming for quantification unit *i* in year *t* in the baseline scenario (t CO_2e/ha)
$EL_{bsl,i,t}$	=	Carbon dioxide emissions from liming for quantification unit *i* in year *t* in the baseline scenario (t CO_2e)

$$EL_{bsl,i,t} = \left((M_{limestone,bsl,i,t} \times EF_{limestone}) + (M_{dolomite,bsl,i,t} \times EF_{dolomite})\right) \times \frac{44}{12} \tag{4}$$

Where:

$M_{limestone,bsl,i,t}$	=	Amount of calcitic limestone ($CaCO_3$) applied to quantification unit *i* in year *t* in the baseline scenario (t)
$EF_{limestone}$	=	Emission factor for calcitic limestone (0.12) (t C/t limestone)
$M_{dolomite,bsl,i,t}$	=	Amount of dolomite ($CaMg(CO_3)_2$) applied to quantification unit *i* in year *t* in the baseline scenario (t)
$EF_{dolomite}$	=	Emission factor for dolomite (0.13) (t C/t dolomite)
44/12	=	Molar mass ratio of carbon dioxide to carbon (dimensionless)

8.2.3 Methane Emissions from Soil Methanogenesis

All project proponents must quantify methane emissions from soil methanogenesis in the baseline scenario, and may select from Quantification Approaches 1, 2, or 3. Where projects with a capacity limit of 60 000 t CO_2e per year use QA3, IPCC Tier 1 global or regional emission factors may be applied. All other projects must use country-specific emission factors when using QA3.

Quantification Approach 1: Modeling

Methane emissions are calculated in the baseline scenario using Equation (5):

$$\overline{CH4\_soil_{bsl,i,t}} = GWP_{\text{CH4}} \times f(CH4\_soil_{bsl,i,t}) \tag{5}$$

Where:

$\overline{CH4\_soil_{bsl,i,t}}$	=	Areal mean methane emissions from soil methanogenesis for quantification unit *i* in year *t* in the baseline scenario (t CO_2e/ha)
GWP_{CH4}	=	Global warming potential for methane (t CO_2e/t CH_4)
$f(CH4\_soil_{bsl,i,t})$	=	Modeled methane emissions from soil methanogenesis for quantification unit *i* in year *t* in the baseline scenario, calculated by modeling soil methane fluxes over the preceding year (t CH_4/ha)

Quantification Approach 2: Direct Measurement

For projects using Quantification Approach 2, the values in Equation (5) for $f(CH4\_soil_{bsl,i,t})$ must be set using the detailed guidance in Section 8.2.4.

Quantification Approach 3: Default Factors (Global/Regional/Country-Specific)

For projects using Quantification Approach 3, the values in Equation (5) for $f(CH4\_soil_{bsl,i,t})$ must be calculated using Equations (6)–(8).

Where root biomass changes significantly relative to baseline conditions, the project proponent must account for the changes in biomass to soil using Equation (7), unless such change in the root biomass is deemed de minimis.

$$EF_{bsl,i,t} = EF_{bsl,c} \times SC_{bsl,w} \times SC_{bsl,p} \times SC_{bsl,o} \quad (6)$$

Where:

$EF_{bsl,i,t}$	=	Adjusted baseline methane emission factor for continuously flooded fields without organic amendments for quantification unit *i* in year *t* (kg CH_4/ha/day)
$EF_{bsl,c}$	=	Baseline methane emission factor for continuously flooded fields without organic amendments (kg CH_4/ha/day)[15]
$SC_{bsl,w}$	=	Baseline scaling factor to account for differences in water regime during the cultivation period; scaling factors must be sourced from Table 5.12 (Updated) in Chapter 5, Volume 4 of the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (unitless)
$SC_{bsl,p}$	=	Baseline scaling factor to account for differences in water regime in the pre-season before the cultivation period; scaling factors must be sourced from Table 5.13 (Updated) in Chapter 5, Volume 4 of the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (unitless)
$SC_{bsl,o}$	=	Baseline scaling factor to account for organic amendments, set using Equation (7) (unitless)

$$SC_{bsl,o} = \left(1 + \sum_{a} ROA_a \times CFOA_a\right)^{0.59} \quad (7)$$

Where:

ROA_a	=	Application rate of organic amendment type *a*, in dry weight for straw and fresh weight for others (t/ha)[16]
$CFOA_a$	=	Conversion factor for organic amendment type *a;* must be sourced from Table 5.14 (Updated) in Chapter 5, Volume 4 of the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (unitless)

[15] Projects with dynamic baseline activities must use the most conservative baseline assumption from a three-year historical look-back period, following the guidance in Section 6, above Table 4. This may mean that a project must set $EF_{bsl,c}$ using the emission factor for single drainage.

[16] For the baseline, 5 t/ha of straw is assumed. This should be adjusted where material changes to biomass management occur in the project, such as increased biomass to soils.

Methane emissions are calculated in the baseline scenario using Equation (8):

$$BE_{CH4,i,t} = EF_{bsl,i,t} \times L_t \times 10^{-3} \times GWP_{CH4} \tag{8}$$

Where:

$BE_{CH4,i,t}$	=	Baseline emissions of methane from soils for quantification unit *i* in year *t* (t CO_2e/ha)
L_t	=	Cultivation period of rice in year *t* (days)[17]

8.2.4 Direct Measurement of Methane Emissions

Where project proponents adopt Quantification Approach 2, direct measurements of methane emissions are made using chamber measurements following the requirements and guidance in this section and in Appendix 2.

The following guidance is structured according to the procedures for field measurement (see Appendix 2) to derive emission factors for each cultivation period specific to the project. Project proponents must make sure that the flux calculations are developed and supervised by experts in this domain or at least experienced staff trained by experts (e.g., from research institutions, governmental agricultural bodies). For each measurement event, the average hourly CH_4 fluxes in a sample unit are calculated using Equations (9)–(12):

$$m_{CH4,pt} = Conc_{CH4,pt} \times Vol_{ch} \times M_{CH4} \times \frac{1\ atm}{R \times T_{pt} \times 1000} \tag{9}$$

Where:

$m_{CH4,pt}$	=	Mass of methane in chamber at time *pt* (mg)
pt	=	Point of time at which sample is taken (e.g., 0, 15, 30 in case of three samples within 30 minutes)
$Conc_{CH4,pt}$	=	Methane concentration in chamber at time *pt* (ppm)
Vol_{ch}	=	Volume of chamber *ch* (L)
M_{CH4}	=	Molar mass of methane (16) (g/mol)
1 atm	=	Assume constant pressure of 1 atm, unless pressure measurement equipment is installed
R	=	Universal gas constant (0.08206) (L atm/K/mol)
T_{pt}	=	Temperature at time *pt* (K)

[17] Each cultivation period commences at land preparation and continues until whichever comes later, harvest or post-season drainage.

Determine the slope of the line of best fit for describing the relationship between $m_{CH4,pt}$ and *pt* using Equation (10).

$$sl = \frac{\Delta m_{CH4,pt}}{\Delta pt} \tag{10}$$

Where:

sl	=	Slope of line of best fit (mg/min)

The hourly flux must be calculated for each chamber measurement in a sample unit:[18]

$$F_{ch} = sl \times \frac{60min}{A_{ch}} \tag{11}$$

Where:

F_{ch}	=	Flux of chamber *ch* (mg/m^2/h)
ch	=	Index for replicate chamber on a sample unit
A_{ch}	=	Basal area of chamber *ch* (m^2)

Calculate the mean hourly flux in a sample unit:

$$F_f = \frac{\sum_{ch=1}^{Nch} F_{ch}}{Nch} \tag{12}$$

Where:

F_f	=	Mean flux for sample unit *f* (mg/m^2/h)
Nch	=	Number of replicate chambers per sample unit

Further Procedure for Calculation of Seasonally Integrated Emission Factor

Once an average emission rate has been calculated for each sample unit, a seasonally integrated emission factor must be calculated by integration of the results of each measurement event over the season length (i.e., cultivation period). The simplest way of integration is multiplying the average emission rate for each sample unit by the number of hours in the measurement interval (e.g., one week = 168 hours) and accumulating the results of every measurement interval over the season. Convert from mg/m^2 to t/ha by multiplying by 10^{-5}. This procedure is outlined in Equations (13)–(15).

[18] This methodology does not prescribe the ideal number of replicate chambers per sample unit. A project expert must determine whether more than one replicate chamber per sample unit is required to minimize the measurement error.

Calculate the total emissions in one measurement interval *z*:

$$E_{f,z} = \frac{(F_{f,z} + F_{f,z+1}) \times 24h \times D_z}{2} \quad (13)$$

Where:

$E_{f,z}$	=	Total emissions in sample unit *f* in interval *z* (mg/m^2)
z	=	Index for weekly measurement interval in season s
F_z	=	Hourly flux at the start of interval *z* ($mg/m^2/h$)
F_{z+1}	=	Hourly flux rate at the end of interval *z* ($mg/m^2/h$)
D_z	=	Number of days in interval *z* (d)

Note – CH_4 flux on planting day and on harvest day may be assumed to be zero where measurement is not implemented on those days.

Calculate the emission factor in sample unit *f* in season *s*:

$$E_{f,s} = \sum_{z=1}^{N} E_{f,z} \quad (14)$$

Where:

$E_{f,s}$	=	Total methane emissions in sample unit *f* in season *s* (mg/m^2)
N	=	Number of measurement intervals *z* in season s

Calculate the emission factor for methane in quantification unit *i* in season *s*:

$$EF_{bsl,i,s} = \frac{\sum_{f=1}^{NF} E_{f,s} \times 10^{-5}}{NF} \quad (15)$$

Where:

$EF_{bsl,i,s}$	=	Emission factor of methane in quantification unit *i* in season s (t CH_4/ha)
NF	=	Number of sample units *f* in quantification unit *i*

Methane emissions are calculated in the baseline scenario using Equation (16):

$$BE_{CH4,i,t} = \sum_{s}^{S} EF_{bsl,i,s} \times GWP_{CH4} \quad (16)$$

Where:

$BE_{CH4,i,t}$	=	Baseline emissions of methane from soils for quantification unit *i* in year *t* (t CO_2e/ha)

8.2.5 Methane Emissions from Biomass Burning

Where CH_4 emissions from biomass burning are included in the project boundary per Table 2, they are quantified in the baseline scenario under QA3 using Equation (17).

$$\overline{CH4\_bb_{bsl,i,t}} = \left(\frac{GWP_{CH4} \times MB_{bsl,i,t} \times CF_r \times EF_{CH4}}{10^6}\right)/A_i \quad (17)$$

Where:

$\overline{CH4\_bb_{bsl,i,t}}$	=	Areal mean methane emissions from biomass burning for quantification unit *i* in year *t* in the baseline scenario (t CO_2e/ha)
GWP_{CH4}	=	Global warming potential for methane (t CO_2e/t CH_4)
$MB_{bsl,i,t}$	=	Mass of rice straw burned for quantification unit *i* in year *t* in the baseline scenario (kg)
CF_r	=	Combustion factor for rice straw expressed as proportion of pre-fire fuel biomass consumed (fraction)
EF_{CH4}	=	Methane emission factor for the burning of rice straw (g CH_4/kg dry matter burned)
10^6	=	Conversion factor from grams to tonnes

8.2.6 Nitrous Oxide Emissions from Nitrogen Fertilizers

Where N_2O emissions due to nitrogen inputs to soils from nitrogen fertilizers and rice straw are included in the project boundary per Table 2, they are quantified in the baseline scenario using the equations below. Nitrous oxide emissions due to nitrification/denitrification include N_2O emissions from nitrogen fertilizers and from nitrogen derived from rice straw.

Where using QA1 and the model domain covers N_2O flux from both fertilizers and rice straw incorporation, only Equation (18) should be used, applying model outputs. Where the model domain does not include both of these sources, Equations (19)–(22) and default emission factors for the given source must be used to generate inputs for Equation (18).

Quantification Approach 1

In Quantification Approach 1, N_2O emissions due to nitrogen inputs to soils (nitrogen fertilizers) in the baseline scenario are quantified as:

$$\overline{N2O\_soil_{bsl,i,t}} = GWP_{N2O} \times f\left(N2O\_soil_{bsl,i,t}\right) \quad (18)$$

Where:

$\overline{N2O\_soil_{bsl,i,t}}$	=	Areal mean nitrous oxide emissions due to nitrogen inputs to soils for quantification unit *i* in year *t* in the baseline scenario (t CO_2e/ha)
GWP_{N2O}	=	Global warming potential for nitrous oxide (t CO_2e/t N_2O)

$f(N20\_soil_{bsl,i,t})$	=	Modeled nitrous oxide emissions from soil for quantification unit *i* in year *t* in the baseline scenario, calculated by modeling soil fluxes of nitrogen forms over the preceding year (t N_2O/ha)

Quantification Approach 3

Where N_2O emissions due to fertilizer use are included in the project boundary per Table 2, they are quantified in the baseline scenario using Equations (19)–(22).

$$\overline{N2O\_soil_{bsl,i,t}} = \left[\left(FSN_{bsl,i,t} + FON_{bsl,i,t} + FCR_{bsl,i,t}\right) \times EF_N\right] \times \frac{44}{28} \times GWP_{N2O}/A_i \quad (19)$$

$$FSN_{bsl,i,t} = \sum_{SF} M_{bsl,SF,i,t} \times NC_{SF} \quad (20)$$

$$FON_{bsl,i,t} = \sum_{OF} M_{bsl,OF,i,t} \times NC_{OF} \quad (21)$$

$$FCR_{bsl,i,t} = \sum_{CR} M_{bsl,CR,i,t} \times NC_{CR} \quad (22)$$

Where:

$\overline{N2O\_soil_{bsl,i,t}}$	=	Areal mean nitrous oxide emissions due to nitrogen inputs to soils for quantification unit *i* in year *t* in the baseline scenario (t CO_2e/ha)
$FSN_{bsl,i,t}$	=	Total nitrogen applied to quantification unit *i* in year *t* as synthetic nitrogen fertilizer in the baseline scenario (t N)
$FON_{bsl,i,t}$	=	Total nitrogen applied to quantification unit *i* in year *t* as organic nitrogen fertilizer in the baseline scenario (t N)
$FCR_{bsl,i,t}$	=	Total nitrogen applied to quantification unit *i* in year *t* as crop residue (aboveground and belowground) nitrogen fertilizer in the baseline scenario (t N)[19]
EF_N	=	Emission factor for nitrous oxide emissions from nitrogen additions from synthetic fertilizers, organic amendments, and crop residues in flooded rice (t N_2O-N/t N applied)
$M_{bsl,SF,i,t}$	=	Mass of nitrogen-containing synthetic fertilizer type *SF* applied to quantification unit *i* in year *t* in the baseline scenario (t)
NC_{SF}	=	Nitrogen content of synthetic fertilizer type *SF* (t N/t fertilizer)

[19] This must include nitrogen from any crop residues left in the field over the off-season period.

$M_{bsl,OF,i,t}$	=	Mass of nitrogen-containing organic fertilizer type *OF* applied to quantification unit *i* in year *t* in the baseline scenario (t)
NC_{OF}	=	Nitrogen content of organic fertilizer type *OF* (t N/t fertilizer)
$M_{bsl,CR,i,t}$	=	Total dry mass of rice straw returned to soils (aboveground and belowground) in quantification unit *i* in year *t* in the baseline scenario (t dry mass)
NC_{CR}	=	Nitrogen content in dry mass of crop residue type *CR* (above- and belowground) before the rice season (t N/t dry mass)
SF	=	Synthetic nitrogen fertilizer type
OF	=	Organic nitrogen fertilizer type
CR	=	Crop residue type (e.g., rice straw)
44/28	=	Molar mass ratio of nitrous oxide to nitrogen

8.2.7 Nitrous Oxide Emissions from Biomass Burning

Where N_2O emissions from biomass burning are included in the project boundary per Table 2, they are quantified in the baseline scenario under QA3 using Equation (23).

$$\overline{N2O\_bb_{bsl,i,t}} = \left(\frac{GWP_{N2O} \times MB_{bsl,i,t} \times CF_r \times EF_{N2O}}{10^6}\right) / A_i \quad (23)$$

Where:

$\overline{N2O\_bb_{bsl,i,t}}$	=	Areal mean nitrous oxide emissions from biomass burning for quantification unit *i* in year *t* in the baseline scenario (t CO_2e/ha)
GWP_{N2O}	=	Global warming potential for nitrous oxide (t CO_2e/t N_2O)
$MB_{bsl,i,t}$	=	Mass of agricultural residues of rice straw burned for quantification unit *i* in year *t* in the baseline scenario (kg)
CF_r	=	Combustion factor for rice straw expressed as proportion of pre-fire fuel biomass consumed (fraction)
EF_{N2O}	=	Nitrous oxide emission factor for the burning of rice straw (g N_2O/kg dry matter burned)
10^6	=	Conversion factor from grams to tonnes

8.3 Project Emissions

Emissions of CO_2, CH_4, and N_2O resulting from project scenario rice cultivation activities are calculated or modeled based on monitored inputs following the approaches found in Table 4 and using the equations provided in Section 8.2. For all equations, the subscript *bsl* must be substituted with *wp* to indicate that the relevant values are being calculated for the project scenario.

In addition to the equations in Section 8.2, other GHG emission sources must be accounted for when implementing any of the following project activities:

1) Where rice straw burning is reduced, project proponents must account for emissions associated with the alternative fate of the rice straw (using Equation (24)).

2) Where irrigation practices are changed, project proponents must account for N_2O emissions associated with such changes by applying an N_2O correction factor (using Equation (25)).

8.3.1 Project Emissions from Diverting Rice Straw to Alternative End-Uses

Where a project materially reduces the amount of rice straw burned, Equation (24) must be used to account for project emissions associated with alternative end uses of the rice straw.

$$PE_{AB,t} = (RS_{removed,r} \times EF_{eu,r} \times 0.001) \tag{24}$$

Where:

$PE_{AB,t}$	=	Project emissions from diverting rice straw to alternative off-farm end uses in year *t* (t CO_2e)
$RS_{removed,r}$	=	Mass of rice straw removed from field and sent to end use category *r* (t d.m.)
$EF_{eu,r}$	=	Emission factor for rice straw for off-farm end use category *r* (kg CO_2e/t dry rice straw)
0.001	=	Unit conversion from kilogram to tonne

8.3.2 Project Emissions of Nitrous Oxide Due to Irrigation Change

All fields that employ changes in irrigation patterns from continuous flooding to AWD (single or multiple drainage) must account for N_2O emissions associated with such changes by applying an N_2O correction factor, regardless of whether there are any changes in the application rate of nitrogen.[20]

$$PE_{Red-Irri,t} = \sum_{i=1}^{n} (Q_{N,i} \times A_i) \times CF_{N2O} \times 10^{-3} \times GWP_{N2O} \tag{25}$$

Where:

$PE_{Red\text{-}Irri,t}$	=	Deduction to account for flux in nitrous oxide emissions due to period of drying on rice fields in year *t* (t CO_2e)
$Q_{N,i}$	=	Application rate of nitrogen input for quantification unit *i* in the project scenario (kg N/ha)

[20] Where project activities include changes (increase or decrease) in N fertilization rates, N_2O emissions must be calculated using the equations in Section 8.2.6.

CF_{N2O}	=	Nitrous oxide correction factor for calculating nitrous oxide emissions flux due to period of drying on rice fields; value of 0.00314 must be used[21] (kg N_2O/kg N-input)
10^{-3}	=	Unit conversion from kilogram to tonne

8.4 Leakage Emissions

Improved rice production projects may result in leakage through:

- new application of organic amendments from outside the project area (i.e., organic amendments applied in the project from outside of the project area that were not previously applied in the historical look-back period);
- declines in rice yield; and/or
- diversion of biomass residues that were used for bioenergy applications in the pre-project scenario.

Guidance on how to account for each type of leakage is provided below.

Where the sum of increases in GHG emissions from any leakage source is less than 5% of the total reductions due to the project activities, such sources may be deemed de minimis and may be ignored. This demonstration must be conducted via application of the CDM *Tool for Testing Significance of GHG Emissions in A/R CDM Project Activities.*

8.4.1 Leakage from New Application of Organic Amendments from Outside the Project Area

Where new[22] or additional[23] manure, compost, or biosolids are applied in the project that were not applied in the historical look-back period, there is a risk of activity-shifting leakage. To account for this type of leakage, a deduction must be used unless any of the following apply:

1) The manure or compost applied in the project is produced on-site from farms within the project area.
2) The manure is documented to have been diverted from an uncontrolled anaerobic lagoon, pond, tank, or pit from which there is no recovery of CH_4 for generation of heat and/or electricity.

[21] The correction factor is derived from the emission factors (kg N_2O-N/t N) from Table 11.1 (Updated), Chapter 11, Volume 4 in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. The difference between the aggregated default value emission factors for continuously flooded rice fields and rice fields with single or multiple drainage was converted from N_2O-N into N_2O emissions. See Appendix 3 for further details.

[22] In this context, “new” refers to organic amendment application to fields that did not have organic amendment applied during the historical look-back period.

[23] In this context, “additional” refers to organic amendment application to fields that had organic amendment applied during the historical look-back period, where the amount of organic amendment increases in the project scenario.

3) The manure, compost, or biosolids are documented to not have been used as a soil amendment.

The deduction represents the portion of manure, compost, or biosolids carbon that remains in the project area without degrading and which would have otherwise been applied to agricultural land outside of the project area.

Equation (26) estimates the leakage from imported manure, compost, or biosolids that are diverted from other applications and could have led to an increase in SOC outside the project boundary in the absence of the project activity. The total amount of carbon applied is reduced to 12% based on the global manure C retention coefficient from Maillard and Angers (2014). This value reflects the fraction of manure carbon expected to remain in the project area. While derived for manure, the equation is also conservatively applied to compost and biosolids in this methodology.

$$LE_{OA,t} = \sum_{l} \left(M\_OA_{wp,l,t} \times CC_{wp,l,t} \times 0.12 \times \frac{44}{12} \right) \tag{26}$$

Where:

$LE_{OA,t}$	=	Leakage from organic amendments in year *t* (t CO_2e)
$M\_OA_{wp,l,t}$	=	Mass of organic amendment (from livestock type *l*) applied as fertilizer in the project area in year *t* (t)
$CC_{wp,l,t}$	=	Carbon content of organic amendment applied as fertilizer in the project area in year *t,* disaggregated by livestock type *l* for manure (t C/t organic amendment)
0.12	=	Fraction of manure carbon expected to remain in project area soils (Maillard and Angers 2014); also applied to other organic amendments (unitless)
44/12	=	Molar mass ratio of carbon dioxide to carbon

Note – as set out in Section 4, project activities that result in a material decline in the volume of biomass to soils in the project are ineligible under this methodology.

8.4.2 Leakage from Rice Yield Declines

Market leakage (LE_{yield}) is likely to be negligible because the land remains in rice production in the project scenario. Further, producers are unlikely to implement and maintain rice production practices that result in productivity declines, since their livelihoods depend on rice yield as a source of income. Nevertheless, to ensure leakage does not occur, the following steps must be completed during the first monitoring period. Where material leakage is detected, the steps must be repeated each season of the project until no material yield decrease is detected. Where no material decrease in yield is detected, these steps need not be repeated until the first monitoring period of the subsequent crediting period.

Step 1: Demonstrate that rice yield has not declined by more than 5% in the monitoring period by one of the following:

1) Comparing average rice yield during the monitoring period (excluding years with extreme weather events) with average baseline rice yield during the historical look-back period, using Equation (27):

$$\Delta P = \left(\frac{P_{wp} - P_{bsl}}{P_{bsl}}\right) \times 100 \quad (27)$$

Where:

ΔP	=	Change in productivity (%)
P_{wp}	=	Average rice yield during the monitoring period (output/ha)
P_{bsl}	=	Average rice yield during the historical look-back period (output/ha)

Or

2) Comparing the ratio of average baseline rice yield to average regional rice yield during the historical look-back period with the ratio of average monitoring period rice yield to average regional rice yield during the monitoring period, using Equation (28) and regional data from government, industry, peer-reviewed, academic, or international organizations (e.g., Food and Agriculture Organization (FAO) or IRRI) sources:

$$\Delta PR = \left(\frac{P_{wp}}{RP_{wp}} - \frac{P_{bsl}}{RP_{bsl}}\right) \times 100 \quad (28)$$

Where:

ΔPR	=	Change in rice yield ratio per hectare (%)
RP_{wp}	=	Average regional rice yield during the monitoring period (output/ha)
RP_{bsl}	=	Average regional rice yield during the historical look-back period (output/ha)

For new rice production techniques introduced as part of the project (e.g., DSR, nitrification inhibitors, reduced rice straw burning) that are not present in the historical look-back period, project proponents should use regional data sources instead of project-specific data sources to determine historical rice yield, and set P_{bsl} equal to RP_{bsl}.

Monitoring period yield averages must be based on data collected in the previous 10 years. Yield averages must not include data that are more than 10 years old. Where yield has improved, stayed constant, or declined by less than 5%, no further action is needed and LE_{yield}

should be set to zero. Where a reduction in yield of greater than 5% is observed, complete Step 2.

Step 2: Determine whether the yield decline was caused by a short-term yield decrease by repeating the calculation in Step 1 and excluding all data inputs from the first three years of project implementation. Where the monitoring period yield with the first three years removed is within 5% of the baseline yield, no further action is needed and LE_{yield} should be set to zero. Where a reduction in yield of greater than 5% is still observed, complete Step 3.

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

1) practice change category,
2) practice change category combinations,
3) soil type, and/or
4) climatic zone.

Where the yield decline is limited to a certain combination of project implementation activities, that combination of project activities becomes ineligible for future crediting, until the yield decline is demonstrated to have been remedied. For example, where a 10% decline in rice yields is observed and stratification shows that the yield decline is linked to fertilizer rate reductions combined with DSR, fertilizer rate reduction practices on DSR fields would no longer be eligible for future crediting until the project monitoring plan is updated to include measures to address the issue, and until the project proponent demonstrates no leakage has occurred. Where a yield decline above 5% is not limited to a certain combination of project implementation activities, the portion of the observed yield decline above 5% is used to set the value for LE_{yield}. Where the project proponent is unable to isolate the source(s) of leakage through stratification, the entire project becomes ineligible for future crediting until the yield decline is demonstrated to have been remedied.

8.4.3 Leakage from Diversion of Biomass Residues Used for Energy Applications in the Baseline Scenario

Where changes in straw management (i.e., due to implementation of avoided biomass burning) is a component of the project activity, and this biomass residue is diverted from the project area (baseline scenario) to energy applications (e.g., fuel for cookstoves or biomass power generation), there is a risk of leakage. Due to implementation of the project activity, these competing applications may be forced to use inputs that are not carbon neutral. Leakage emissions due to the diversion of biomass residues used in the baseline for renewable fuel production ($LE_{BR,t}$) must be determined following procedures in CDM *TOOL16 Project and Leakage Emissions from Biomass*.[24]

[24] Available at: https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-16-v2.pdf/history_view

8.5 Net Reductions

Emission reductions are calculated by subtracting baseline (subscript *bsl*) from project (subscript *wp*) emissions. Equation (29) is used to calculate net reductions under Quantification Approaches 1, 2, and 3. $UNC_{t,CH4\_soil}$ and $UNC_{t,N2O\_soil}$ must be calculated in accordance with the guidance in Section 8.6.4. Projects using Quantification Approach 3 that have a capacity limit of 60 000 t CO_2e per year must use a 15% default uncertainty deduction.

$$ER_t = \Delta CO2\_ff_t + \Delta CO2\_lime_t + \Delta CH4\_bb_t + \left(\Delta CH4\_soil_t \times \left(1 - UNC_{CH4\_soil,t}\right)\right) + \left(\Delta N2O\_soil_t \times \left(1 - UNC_{N2O\_soil,t}\right)\right) + \Delta N2O\_bb_t - LE_{OA,t} - LE_{BR,t} - PE_{AB,t} - PE_{Red-Irri,t} \quad (29)$$

Where:

ER_t	=	Estimated net reductions in year *t* (t CO_2e)
$\Delta CO2\_ff_t$	=	Total carbon dioxide reductions from fossil fuel combustion in year *t* (t CO_2e)
$\Delta CO2\_lime_t$	=	Total carbon dioxide reductions from liming in year *t* (t CO_2e)
$\Delta CH4\_bb_t$	=	Total methane reductions from avoided or reduced biomass burning in year *t* (t CO_2e)
$\Delta CH4\_soil_t$	=	Total methane reductions from soils in year *t* (t CO_2e)
$UNC_{CH4\_soil,t}$	=	Uncertainty deduction for methane emissions in year *t* (fraction between 0 and 1)
$\Delta N2O\_soil_t$	=	Total nitrous oxide reductions from nitrification/denitrification in year *t* (t CO_2e)
$UNC_{N2O\_soil,t}$	=	Uncertainty deduction for nitrous oxide emissions in year *t*
$\Delta N2O\_bb_t$	=	Total nitrous oxide reductions from avoided or reduced biomass burning in year *t* (t CO_2e)
$LE_{BR,t}$	=	Leakage from diversion of biomass residues used for energy application in the baseline scenario, derived from Section 8.4.3

8.5.1 Fossil Fuel Combustion Emission Reductions ($\Delta CO2\_ff_t$)

Emissions impacts of changes in fossil fuel usage are quantified as follows:

$$\Delta CO2\_fft = \sum_{i=1}^{n} \left(\overline{CO2\_ff_{bsl,i,t}} - \overline{CO2\_ff_{wp,i,t}} \right) \times A_i \quad (30)$$

Where:

$\overline{CO2\_ff_{wp,i,t}}$	=	Areal mean carbon dioxide emissions from fossil fuel combustion for quantification unit *i* in year *t* in the project scenario (t CO_2e/ha)

8.5.2 Methane Emission Reductions ($\Delta CH4_t$)

Methane reductions from soil methanogenesis are quantified as follows:

$$\Delta CH4\_soil_t = \sum_{i=1}^{n}\left(\overline{CH4\_soil_{bsl,i,t}} - \overline{CH4\_soil_{wp,i,t}}\right) \times A_i \tag{31}$$

Where:

$\overline{CH4\_soil_{wp,i,t}}$ = Areal mean methane emissions from soil methanogenesis for quantification unit *i* in year *t* in the project scenario (t CO_2e/ha)

Methane reductions from avoided or reduced biomass burning are quantified as follows:

$$\Delta CH4\_bb_t = \sum_{i=1}^{n}\left(\overline{CH4\_bb_{bsl,i,t}} - \overline{CH4\_bb_{wp,i,t}}\right) \times A_i \tag{32}$$

Where:

$\overline{CH4\_bb_{wp,i,t}}$ = Areal mean methane emissions from biomass burning for quantification unit *i* in year *t* in the project scenario (t CO_2e/ha)

8.5.3 Nitrous Oxide Emission Reductions ($\Delta N2O_t$)

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

$$\Delta N2O\_soil_t = \sum_{i=1}^{n}\left(\overline{N2O\_soil_{bsl,i,t}} - \overline{N2O\_soil_{wp,i,t}}\right) \times A_i \tag{33}$$

Where:

$\overline{N2O\_soil_{wp,i,t}}$ = Areal mean nitrous oxide emissions due to nitrogen inputs to soils for quantification unit *i* in year *t* in the project scenario (t CO_2e/ha)

Nitrous oxide reductions from biomass burning are quantified as follows:

$$\Delta N2O\_bb_t = \sum_{i=1}^{n}\left(\overline{N2O\_bb_{bsl,i,t}} - \overline{N2O\_bb_{wp,i,t}}\right) \times A_i \tag{34}$$

Where:

$\overline{N2O\_bb_{wp,i,t}}$ = Areal mean nitrous oxide emissions from biomass burning for quantification unit *i* in year *t* in the project scenario (t CO_2e/ha)

8.6 Uncertainty

Uncertainty deductions are estimated separately for each GHG source within a project. Deductions are based on an estimate of the total error of the project's calculated reductions for that source over a given verification period. Key sources of uncertainty that contribute to this error differ for each quantification approach. This section details these sources of error and methods to estimate such errors for use in an uncertainty assessment and calculation of the required uncertainty deduction.

Under Quantification Approaches 1 and 2, the uncertainty guidance provided here assumes that all gas sampling/analysis and modeling occurs on a point basis. In other words, the model results and/or direct gas sample measurements each represent a single point in space at which initial management data have been collected, and uncertainty is calculated by combining estimates of sampling, modeling, and measurement error based on the design chosen to select the points. Alternative approaches (e.g., modeling on an areal basis) are considered a deviation and project proponents must demonstrate that such approaches will not negatively impact the conservativeness of reduction estimates per the most recent version of the *VCS Standard*.[25]

Across Quantification Approaches 1 and 2, a key source of error is sampling error, which emerges from only being able to measure/model a portion of the total project area. Appropriate estimates of this source of error are specific to the sample design employed.

This methodology requires stratification of the project area. Each stratum should be based on physical and management factors (see Appendix 2) that minimize within-stratum variability. Data from each quantification unit must be collected for all three quantification approaches. Under QA2, control sites must be allocated within each stratum based on recommendations from an expert; refer to Appendix 3 for details on direct gas chamber measurements. The remainder of this section is based on a simplified example of a stratified random sampling design in which the entire project is divided into strata and points within those strata are placed using simple random sampling with replacement.

8.6.1 Quantification Approach 1

Quantification Approach 1 is a modeling approach in which a biogeochemical model is used to simulate changes in CH_4 and/or N_2O fluxes over a given time period in both the project and baseline scenarios. Initial measurements of SOC must be taken at the project start[26] and used for model initialization. Project proponents must follow the guidance in *VMD0053* and Section 8.6.1 of *VM0042, v2.1*[27] with respect to uncertainty calculations while using modeling under Quantification Approach 1.

Key sources of error accounted for under Quantification Approach 1 include:

[25] Section 3.20 in the *VCS Standard, v4.7*

[26] Initial measurements of SOC may be conducted at t = 0 or (back-) modeled to t = 0 from measurements collected within ±5 years of t = 0. This time frame (5 years) should be shortened where possible. For projects with more than one project crediting period (i.e., more than a 10-year cycle), SOC measurements must be taken for each crediting renewal period.

[27] Or equivalent section in the most recent version

- **Model prediction error** resulting from uncertainty in model parameters or model structural errors (i.e., inaccurate representation of actual biogeochemical processes). Model prediction error is calculated using independent statistical validation datasets per the processes outlined in *VMD0053*. Alternatively, project proponents may account for model prediction error by calibrating models to include parameter uncertainty (e.g., a Bayesian implementation of the model) and using the Monte Carlo simulation or error propagation approach.
- **Sampling error** resulting from measuring/modeling only a portion of the project area. Estimates of sampling error are contingent on the sampling design employed by the project proponent.
- **Measurement error** of model inputs. In many cases, the impact of these measurement errors on the error of reduction estimates is assumed to be captured in model prediction error and/or sampling error. In this case, Monte Carlo simulation is required unless it is demonstrated that such errors have a de minimis effect on model estimates of reductions.

For each GHG flux, these sources of error are estimated separately and then combined to estimate a single uncertainty deduction for that GHG flux across the entire project. Two approaches are eligible to estimate the uncertainty:

1) Analytical calculation of error propagation

2) Monte Carlo simulation

Guidance on performing a Monte Carlo simulation is found in Section 8.6.1.1 of *VM0042, v2.1*.[28]

8.6.2 Quantification Approach 2

Quantification Approach 2 is applicable for CH_4 flux measurements. The baseline is represented by control sites that are linked to one or more strata. The CH_4 flux difference and its uncertainty is calculated based on comparisons of control sites and paired strata. Key sources of error accounted for under QA2 include:

- **Sampling error** derived from only measuring a subset of the entire project area, resulting in a potentially inaccurate estimate of the true variance of CH_4 flux. Sampling error is determined by calculating the approximate standard error of CH_4 flux as directly measured following the guidance in Appendix 2.
- **Measurement error** of methods used to determine CH_4 flux measurements at sample points. Where samples are collected in accordance with the guidance in Appendix 3 and tested in a laboratory with demonstrated proficiency and quality control (e.g.,

[28] Ibid.

through participation in the North American Proficiency Testing program), these errors are assumed to be unbiased and negligible.

These sources of error are estimated separately and then combined to estimate a single uncertainty deduction for CH_4 flux across the entire project. Similar to QA1, an analytical error propagation or Monte Carlo simulation method may be used. The Monte Carlo simulation method is more appropriate in cases where measurement error is deemed significant and must be propagated through calculations.

The various sources of error outlined above are independently estimated for each CH_4 flux that results in a reduction. The estimated errors are then combined to provide an estimate of the total variance of the areal mean reductions across the project for each source in each verification period ($s^2_{\Delta\bullet,t}$). This is used to determine an appropriate uncertainty deduction.

This section is based on a stratified random sampling design in which the entire project area is divided into strata, and sites for gas measurements (i.e., baseline control sites and sample units) are allocated within each stratum.[29] Methane flux measurements are collected at these points in the quantification units and/or control sites. Formulas for uncertainty estimators are drawn from Som (1995, ch. 10). Project-specific strata, their area, and the sampling points (quantification units and/or control sites) within strata must be reported in a spreadsheet and submitted as an annex to project documentation at every verification. This information feeds into Equation (35) for the parameters stratum identifier (*h*), area of stratum (A_h), and sample point identifier (*ip*).

$$S^2_{sampling,\Delta\bullet,t} = \sum_{h=1}^{H} S^2_{sampling,\Delta\bullet,h,t} \quad (35)$$

Where:

$$S^2_{sampling,\Delta\bullet,h,t} = \frac{A_h^2}{n_h(n_h-1)} \sum_{ip=1}^{n_h} \left(\Delta\bullet_{h,ip,t} - \overline{\Delta\bullet_{h,t}}\right)^2 \quad (36)$$

And:

$S^2_{sampling,\Delta\bullet,t}$	=	Variance of reductions in gas • due to sampling error at time *t* across the entire project area (t CO_2e)^2
$S^2_{sampling,\Delta\bullet,h,t}$	=	Variance of reductions in gas • within stratum *h* due to sampling error at time *t* (t CO_2e)^2
$\overline{\Delta\bullet_{h,t}}$	=	Areal mean reduction in gas • in stratum *h* at time *t*, computed as the average across the sample points in stratum *h* (t CO_2e/ha)

[29] While applying random sampling, the selection of sites for gas measurements should consider site accessibility, and the project proponent must justify the choice of sampling allocation.

$\Delta \bullet_{h,ip,t}$	=	Estimated reduction in gas • on an area basis in year *t* in stratum *h* at point *ip* (t CO_2e/ha)
h	=	1, …, *H* strata across the entire project area
ip	=	1, …, n_h sample points (gas chamber) within stratum *h*
A_h	=	Area of stratum *h*

The variance of $\overline{\Delta \bullet_t}$ incorporating sample uncertainty is estimated by dividing the variance estimates of error sources by the square of the total project area (Cochran 1977, Eq. 13.39; Som 1995, Eq. 25.10).

$$S^2_{\overline{\Delta \bullet},t} = \frac{S^2_{sampling,\Delta \bullet,t}}{A^2} \tag{37}$$

Where:

$S^2_{\overline{\Delta \bullet},t}$	=	Variance of the estimate of mean reductions in gas • at time *t* (t CO_2e/ha)^2
A	=	Total project area (ha)

8.6.3 Quantification Approach 3

The uncertainty approach for CH_4 and N_2O from soils varies depending on emission factor tiers and project scale. Project proponents using global or regional IPCC Tier 1 emission factors for projects with a capacity limit of 60 000 t CO_2e per year must apply a standardized default uncertainty deduction of 15%. Project proponents using country-specific emission factors for projects with estimated reductions above 60 000 t CO_2e per year must calculate the uncertainty associated with the applied emission factors.

Project proponents may derive country-specific emission factors using literature, following the guidance to derive Tier 2 emission factors in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Uncertainty estimates must be derived from the source literature or otherwise calculated in accordance with the above guidance for estimating uncertainty using analytical calculation of error propagation or Monte Carlo simulation (Section 8.6.1). While these emission factors likely include some prediction error, availability of source data for estimating that error may be inconsistent. As such, the prediction error of emission factors is presumed to be zero for the purpose of calculating an uncertainty deduction. Project proponents must use the available emission factor that results in the most conservative reduction estimates when applied across both the baseline and project scenarios.

Uncertainty of fossil fuel burning and liming default emission factors is expected to be lower than 10%[30] and is conservatively excluded from calculations. Uncertainty of biomass burning

[30] Refer to guidelines from Chapter 3, Vol. 1 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_3_Ch3_Uncertainties.pdf

default emission factors may be higher than 10%, but the relative contribution to total uncertainty is expected to be small and it is therefore excluded from calculations.

8.6.4 Uncertainty Deductions

Uncertainty deductions are estimated and applied separately for each source of reductions within the project boundary. This deduction is estimated using a probability of exceedance method as follows (see Section 2.4 of the *VCS Methodology Requirements, v4.4*):

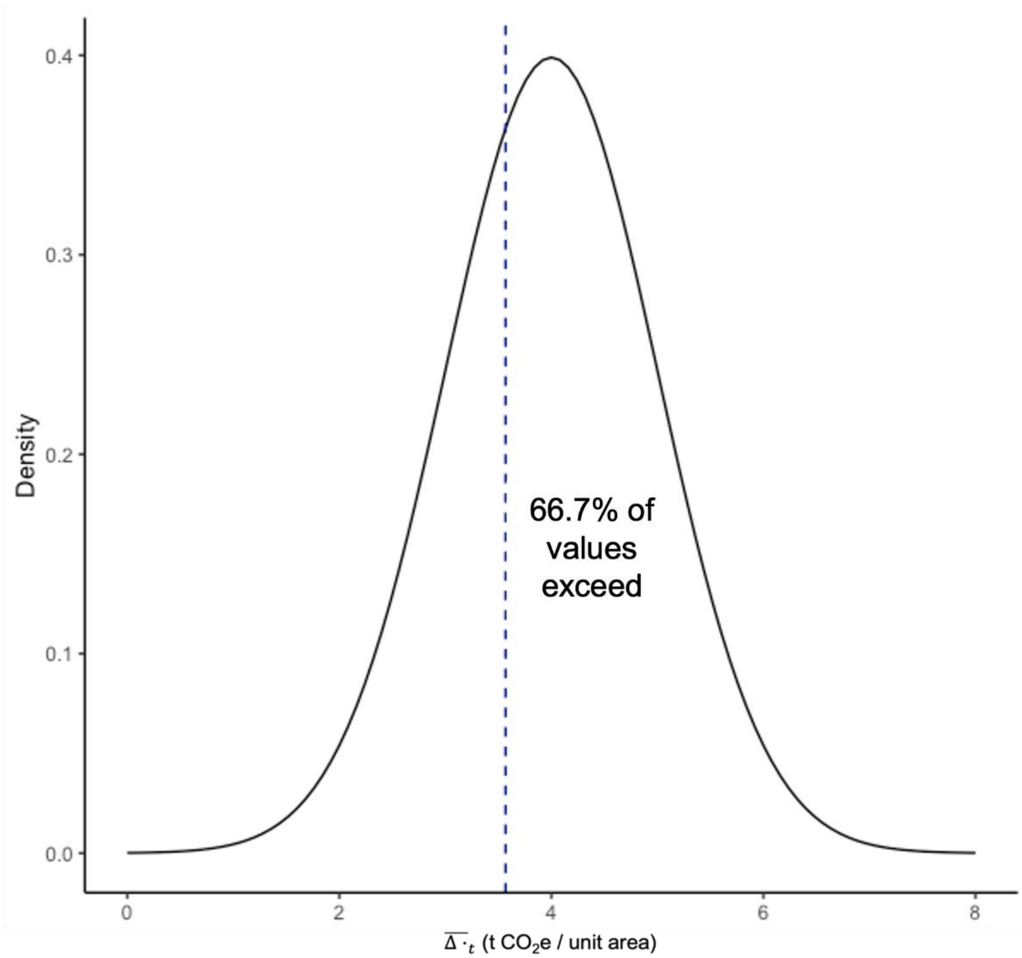
$$UNC_{\overline{\Delta\bullet},t} = \left(\frac{\sqrt{s^2_{\overline{\Delta\bullet},t}}}{\overline{\Delta\bullet}_t} \times 100\right) \times t_{0.667} \quad (38)$$

Where:

$UNC_{\overline{\Delta\bullet},t}$	=	Uncertainty deduction for gas • to be applied in verification period *t* (%)
$\overline{\Delta\bullet}_t$	=	Mean estimated reduction in gas • across the entire project area in year *t* (t CO_2e/ha)
$t_{\alpha=0.667}$	=	Critical value of a one-sided student's t-distribution at significance level α = 0.667 (66.7%) with degrees of freedom appropriate to the sampling design used; equal to approximately 0.4307 at large sample sizes (dimensionless)

This uncertainty deduction is based on a defined threshold in the estimated probability density function of the reduction for a given source. This enables a judgment of the extent to which the achieved reduction by the project may be expected to be accurate. By this procedure, estimate what proportion of the estimates of $\overline{\Delta\bullet}_t$ would have a 66.7% probability of exceeding the true value of $\overline{\Delta\bullet}_t$. That proportion is then used as a percentage uncertainty deduction. Where it is unlikely that the half-width of the two-sided 90% percent confidence interval for estimating reductions could exceed 10% of the estimated value, random uncertainty may be excluded. Where the half-width of the two-sided 90% confidence interval exceeds 100% of the reduction estimate, the project is not eligible for crediting. Figure 2 demonstrates this concept.

Figure 2. Probability of exceedance. The value for $\overline{\Delta \bullet}_t$ used in calculation of net reductions is determined by applying an uncertainty deduction based on the 33.3rd percentile of the estimated probability distribution of $\overline{\Delta \cdot}_t$



9 MONITORING

9.1 Data and Parameters Available at Validation

Data/Parameter	$FFC_{bsl,i,j,t}$
Data unit	liters
Description	Consumption of fossil fuel type *j* for quantification unit *i* in year *t* in the baseline scenario
Equations	(2)
Source of data	See Box 1.
Value applied	See Box 1.
Justification of choice of data or description of measurement methods and procedures applied	Fossil fuel consumption may be monitored or the amount of fossil fuel combusted may be estimated using fuel efficiency (e.g., L/100 km, L/km, L/hour) of the vehicle and the appropriate unit of use for the selected fuel efficiency (e.g., km driven where efficiency is given in L/100 km).
Purpose of data	Calculation of baseline and project emissions
Comments	Fuel efficiency may be obtained from peer-reviewed studies or the most recent version of the IPCC guidelines (Volume 2, Chapter 3). For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	$M_{limestone,bsl,i,t}$ $M_{dolomite,bsl,i,t}$
Data unit	tonnes
Description	Amount of calcitic limestone ($CaCO_3$) applied to quantification unit *i* in year *t* in the baseline scenario Amount of dolomite ($CaMg(CO_3)_2$) applied to quantification unit *i* in year *t* in the baseline scenario
Equations	(4)
Source of data	See Box 1.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	All limestone and dolomite applied to soils should be included, even the proportion applied in mixture with fertilizers. Use of oxides (e.g., CaO) and hydroxides of lime for soil liming need not be included in the calculations to estimate CO_2 emissions from liming. As these materials do not contain inorganic carbon, CO_2 is not released following soil application; it is only produced during material manufacture.
Purpose of data	Calculation of baseline and project emissions

Comments	For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	GWP_{CH4}
Data unit	t CO_2e/t CH_4
Description	Global warming potential for methane
Equations	(5), (8), (16), (17)
Source of data	Most recent version of the *VCS Standard*
Value applied	See the most recent version of the *VCS Standard*.
Justification of choice of data or description of measurement methods and procedures applied	The *VCS Standard* provides the GWPs that must be used under the VCS Program.
Purpose of data	Calculation of baseline and project emissions
Comments	None

Data/Parameter	$EF_{bsl,c}$
Data unit	kg CH_4/ha/day
Description	Baseline methane emission factor for continuously flooded fields without organic amendments
Equations	(6)
Source of data	Most recent version of IPCC guidelines (Table 5.11, Chapter 5, Volume 4)
Value applied	Value depends on the country in which the project area is located. See Table 5.11 in data source.
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	Default values are to be considered at a country-specific, regional, and global level, listed here in descending order of preference.

Data/Parameter	$SC_{bsl,w}$
Data unit	unitless

Description	Baseline scaling factor to account for differences in water regime during the cultivation period
Equations	(6)
Source of data	Most recent version of IPCC guidelines (Table 5.12, Chapter 5, Volume 4)
Value applied	Value depends on water regime employed. Values from IPCC (2019) are: • Continuously flooded: 1 • Single drainage period: 0.71 • Multiple drainage periods: 0.55
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	For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	$SC_{bsl,p}$
Data unit	unitless
Description	Baseline scaling factor to account for differences in water regime in the pre-season before the cultivation period
Equations	(6)
Source of data	Most recent version of IPCC guidelines (Table 5.13, Chapter 5, Volume 4)
Value applied	Value depends on water regime employed. Values from IPCC (2019) are: • Non-flooded pre-season <180 days (indicating double cropping): 1.00 • Non flooded pre-season >180 days (indicating single cropping): 0.89
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	For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	$CFOA_a$
Data unit	unitless

Description	Conversion factor for organic amendment type *a*
Equations	(7)
Source of data	Most recent version of IPCC guidelines (Table 5.14, Chapter 5, Volume 4)
Value applied	Value depends on organic amendment type applied (see Section 8.2.3)
Justification of choice of data or description of measurement methods and procedures applied	See "Source of data." Where the project involves the introduction of a new cultivar that is known to have a materially larger root system to the cultivar(s) being deployed in the baseline, the change in root biomass must be accounted for using this conversion factor.
Purpose of data	Calculation of baseline and project emissions
Comments	None

Data/Parameter	$MB_{bsl,i,t}$
Data unit	kg
Description	Mass of rice straw burned for quantification unit *i* in year *t* in the baseline scenario
Equations	(17), (23)
Source of data	See Box 1.
Value applied	See Box 1.
Justification of choice of data or description of measurement methods and procedures applied	Peer-reviewed published data may be used to estimate aboveground biomass prior to burning.
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 remaining residues are burned. It is assumed that 100% of aboveground biomass is burned in the baseline scenario. For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	GWP_{N2O}
Data unit	t CO_2e/t N_2O
Description	Global warming potential for nitrous oxide
Equations	(18), (19), (23), (25)
Source of data	Most recent version of the *VCS Standard*

Value applied	See the most recent version of the *VCS Standard.*
Justification of choice of data or description of measurement methods and procedures applied	The *VCS Standard* provides the GWPs that must be used under the VCS Program.
Purpose of data	Calculation of baseline and project emissions
Comments	None

Data/Parameter	CF_{N2O}
Data unit	kg N_2O/kg N-input
Description	N_2O correction factor for calculating N_2O emissions flux due to period of drying on rice fields
Equations	(25)
Source of data	The correction factor is derived from the emission factors (kg N_2O-N/t N) from the most recent version of Table 11.1 (Updated) in Chapter 11, Volume 4 in the IPCC guidelines. The difference between the aggregated default value emission factors for continuously flooded rice fields and rice fields with single or multiple drainage was converted from N_2O-N into N_2O emissions. See Appendix 3 for further details on how the correction factor was derived.
Value applied	0.00314 (IPCC 2019)
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	P_{bsl}
Data unit	output/ha
Description	Average rice yield during the historical look-back period
Equations	(27), (28)
Source of data	See Box 1.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Average productivity for each livestock/crop following guidance in Section 8.4.2.

Purpose of data	Calculation of leakage
Comments	For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	RP_{bsl}
Data unit	output/ha
Description	Average regional rice yield during the historical look-back period
Equations	(28)
Source of data	Secondary evidence sources of regional productivity (e.g., peer-reviewed literature, industry associations, international databases, government databases)
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Average regional productivity for each livestock/crop product following guidance in Section 8.4.2.
Purpose of data	Calculation of leakage
Comments	For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

9.2 Data and Parameters Monitored

Data/Parameter	A_i
Data unit	ha
Description	Area of quantification unit *i*
Equations	(1), (3), (17), (19), (23), (25), (30)–(34)
Source of data	Measurement of each quantification unit within the project area
Description of measurement methods and procedures to be applied	The quantification unit area is measured prior to verification.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	Delineation of the quantification unit area may be determined using a combination of geographic information system (GIS) coverages, ground survey data, remote imagery (satellite or aerial photographs), and other appropriate data. Any imagery or GIS datasets used must be geo-

	registered referencing corner points, landmarks, or other intersection points.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	Other units used to determine area (e.g., acres) must be converted to hectares.

Data/Parameter	$EF_{CO2,j}$
Data unit	t CO_2e/liter
Description	Emission factor for combustion of fossil fuel type *j*
Equations	(2)
Source of data	Most recent version of IPCC guidelines (Table 3.3.1 in Chapter 3, Volume 2)
Description of measurement methods and procedures to be applied	From IPCC (2019): • gasoline EF_{CO2} = 0.002810 t CO_2e per liter • diesel EF_{CO2} = 0.002886 t CO_2e per liter
Frequency of monitoring/recording	Source of data for emission factor must be monitored every five years and must be updated when more accurate data applicable to the project conditions become available.
QA/QC procedures to be applied	See "Source of data."
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	Assumes four-stroke gasoline engine for gasoline combustion and default values for energy content of 44.3 GJ/t and 43.0 GJ/t for gasoline and diesel respectively (IPCC 2006).

Data/Parameter	$EF_{limestone}$ $EF_{dolomite}$
Data unit	t C/t limestone t C/t dolomite
Description	Emission factor for calcitic limestone ($CaCO_3$) Emission factor for dolomite ($CaMg(CO_3)_2$)
Equations	(4)
Source of data	Most recent version of IPCC guidelines (Section 11.3, Chapter 11, Volume 4)
Description of measurement methods	IPCC (2019) values:

and procedures to be applied	• $EF_{limestone}$ = 0.12 t C/t limestone • $EF_{dolomite}$ = 0.13 t C/t dolomite
Frequency of monitoring/recording	Source of data for emission factor must be monitored every five years and must be updated when more accurate data applicable to the project conditions become available.
QA/QC procedures to be applied	See "Source of data" and the guidance in Section 8.1.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	$f(CH4\_soil_{bsl,i,t})$
Data unit	t CH_4/ha
Description	Modeled methane emissions from soil methanogenesis for quantification unit *i* in year *t* in the baseline scenario, calculated by modeling soil methane fluxes over the preceding year
Equations	(5)
Source of data	Modeled in the project area
Description of measurement methods and procedures to be applied	Modeled CH_4 emissions from soil methanogenesis in the baseline scenario are determined according to the following equation: $f(CH4\_soil_{bsl,i,t}) = fCH4soil(Val\ A_{bsl,i,t}, Val\ B_{bsl,i,t}, \ldots)$ Where: $f(CH4\_soil_{bsl,i,t})$ = Modeled methane emissions from soil methanogenesis for quantification unit *i* in year *t* in the baseline scenario (t CH_4/ha) $fCH4soil$ = Model predicting methane emissions from soil methanogenesis $Val\ A_{bsl,i,t}$ = Value of model input variable A for quantification unit *i* at time *t* in the baseline scenario (units unspecified) $Val\ B_{bsl,i,t}$ = Value of model input variable B for quantification unit *i* at time *t* in the baseline scenario (units unspecified) See Box 1 for sources of data and description of measurement methods and procedures to be applied to obtain values for model input variables.
Frequency of monitoring/recording	Monitoring must be conducted annually or prior to each verification event where verification occurs more frequently.
QA/QC procedures to be applied	See *VMD0053*.
Purpose of data	Calculation of baseline and project emissions (QA1)

Calculation method	Methods are specific to model used.
Comments	For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	ROA_a
Data unit	t/ha
Description	Application rate of organic amendment type *a,* in dry weight of straw and fresh weight for others
Equations	(7)
Source of data	Management records from project area
Description of measurement methods and procedures to be applied	See Box 1. In the baseline scenario, 5 t/ha of straw is assumed. This should be adjusted where material changes in biomass management occur in the project, such as increased biomass to soils.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	See Box 1.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	L_t
Data unit	days
Description	Cultivation period of rice in year *t*
Equations	(8)
Source of data	Farm management records In circumstances where climatic conditions result in a monitoring period's cultivation period lasting longer than the baseline cultivation period, project proponents may set the baseline cultivation period duration as the actual number of days in the cultivation period during the monitoring period.
Description of measurement methods and procedures to be applied	See Box 1. Each cultivation period commences at land preparation and continues until whichever comes later, harvest or post-season drainage.

Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	See Box 1.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	$Conc_{CH4,pt}$
Data unit	ppm
Description	Methane concentration in chamber at time *pt*
Equations	(9)
Source of data	Measured in the project area
Description of measurement methods and procedures to be applied	See Appendix 2.
Frequency of monitoring/recording	Monitoring must be conducted annually or prior to each verification event where verification occurs more frequently.
QA/QC procedures to be applied	See Appendix 2.
Purpose of data	Calculation of baseline and project emissions (QA2)
Calculation method	N/A
Comments	None

Data/Parameter	Vol_{ch}
Data unit	liters
Description	Volume of chamber *ch*
Equations	(9)
Source of data	Measurements of the chamber based on the height, width and length.
Description of measurement methods and procedures to be applied	See Appendix 2.

Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	See Appendix 2.
Purpose of data	Calculation of baseline and project emissions (QA2)
Calculation method	N/A
Comments	None

Data/Parameter	T_{pt}
Data unit	Kelvin
Description	Temperature at time *pt*
Equations	(9)
Source of data	Measured
Description of measurement methods and procedures to be applied	See Appendix 2.
Frequency of monitoring/recording	Monitoring must be conducted annually or prior to each verification event where verification occurs more frequently.
QA/QC procedures to be applied	See Appendix 2.
Purpose of data	Calculation of baseline and project emissions (QA2)
Calculation method	N/A
Comments	None

Data/Parameter	A_{ch}
Data unit	m^2
Description	Basal area of chamber *ch*
Equations	(11)
Source of data	Measured
Description of measurement methods and procedures to be applied	See Appendix 2.
Frequency of monitoring/recording	Must be monitored once per chamber.

QA/QC procedures to be applied	See Appendix 2.
Purpose of data	Calculation of baseline and project emissions (QA2)
Calculation method	N/A
Comments	None

Data/Parameter	*Nch*
Data unit	Dimensionless
Description	Number of replicate chambers per sample unit
Equations	(12)
Source of data	Measured
Description of measurement methods and procedures to be applied	See Appendix 2.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	See Appendix 2.
Purpose of data	Calculation of baseline and project emissions (QA2)
Calculation method	N/A
Comments	None

Data/Parameter	CF_r
Data unit	fraction
Description	Combustion factor for rice straw expressed as proportion of pre-fire fuel biomass consumed
Equations	(17), (23)
Source of data	Most recent version of IPCC guidelines (Table 2.6 in Chapter 2, Volume 4)
Description of measurement methods and procedures to be applied	IPCC (2019) value: 0.80
Frequency of monitoring/recording	Source of data for combustion factor must be monitored every five years and must be updated when more accurate data applicable to the project conditions become available.

QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	EF_{CH4}
Data unit	g CH_4/kg dry matter burned
Description	Methane emission factor for the burning of rice straw
Equations	(17)
Source of data	Most recent version of IPCC guidelines (Table 2.5 in Chapter 2, Volume 4)
Description of measurement methods and procedures to be applied	IPCC (2019) value: 2.7
Frequency of monitoring/recording	Source of data for the emission factor must be monitored every five years and must be updated when more accurate data applicable to the project conditions become available.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	$f(N2O\_soil_{bsl,i,t})$
Data unit	t N_2O/ha
Description	Modeled nitrous oxide emissions from soil for quantification unit *i* in year *t* in the baseline scenario, calculated by modeling soil fluxes of nitrogen forms over the preceding year
Equations	(18)
Source of data	Modeled in the project area
Description of measurement methods and procedures to be applied	Modeled N_2O emissions from soil in the baseline scenario are determined according to the following equation: $f(N2O\_soil_{bsl,i,t}) = f N2O_{soil}(Val\ A_{bsl,i,t}, Val\ B_{bsl,i,t}, \ldots)$ Where:

	$f(N2O\_soil_{bsl,i,t})$ = Modeled nitrous oxide emissions from soil for quantification unit *i* in year *t* in the baseline scenario (t N_2O/ha) $fN2O_{soil}$ = Model predicting nitrous oxide emissions from soils $Val\ A_{bsl,i,t}$ = Value of model input variable A for quantification unit *i* at time *t* in the baseline scenario (units unspecified) $Val\ B_{bsl,i,t}$ = Value of model input variable B for quantification unit *i* at time *t* in the baseline scenario (units unspecified) See Box 1 for sources of data and description of measurement methods and procedures to be applied to obtain values for model input variables.
Frequency of monitoring/recording	Monitoring must be conducted annually or prior to each verification event where verification occurs more frequently.
QA/QC procedures to be applied	See *VMD0053.*
Purpose of data	Calculation of baseline and project emissions (QA1)
Calculation method	N/A
Comments	For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	EF_N
Data unit	(t N_2O-N/t N applied)
Description	Emission factor for nitrous oxide emissions from nitrogen additions from synthetic fertilizers, organic amendments, and crop residues in flooded rice
Equations	(20)
Source of data	See Section 8.2.6 under Quantification Approach 3. Where no information source is available that is applicable to the project conditions, project proponents may derive emission factors following the guidance in Chapter 11, Section 11.2.1.1 and Chapter 2, Section 2.2.2 in Volume 4 of IPCC (2019). Where project proponents justify a lack of sufficient activity data and project-specific information sources, an appropriate disaggregated Tier 1 value from Table 11.1, Chapter 11, Volume 4 in IPCC (2019) may be selected.
Description of measurement methods and procedures to be applied	See “Source of data.”
Frequency of monitoring/recording	Source of data for emission factor must be monitored every five years and must be updated when more accurate data applicable to the project conditions become available.

QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	*SF*
Data unit	dimensionless
Description	Synthetic nitrogen fertilizer type
Equations	(20)
Source of data	Determined in quantification unit *i*
Description of measurement methods and procedures to be applied	See Box 1. Synthetic fertilizer type is determined prior to verification.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	NC_{SF}
Data unit	t N/t fertilizer
Description	Nitrogen content of synthetic fertilizer type *SF*
Equations	(20)
Source of data	See Box 1.
Description of measurement methods and procedures to be applied	N content is determined following the fertilizer manufacturer's specifications.
Frequency of monitoring/recording	Monitoring must be conducted each season. Parameter value must be updated when synthetic fertilizer product is changed or when new manufacturer specifications are issued.

QA/QC procedures to be applied	See "Source of data" and Quantification Approach 3 in Section 8.2.6.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	$M_{bsl,SF,i,t}$
Data unit	tonnes
Description	Mass of nitrogen-containing synthetic fertilizer type *SF* applied to quantification unit *i* in year *t* in the baseline scenario
Equations	(20)
Source of data	Management records from project area
Description of measurement methods and procedures to be applied	See Box 1.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	*OF*
Data unit	dimensionless
Description	Organic nitrogen fertilizer type
Equations	(21)
Source of data	Determined in quantification unit *i*
Description of measurement methods and procedures to be applied	See Box 1. Organic fertilizer type is determined prior to verification.
Frequency of monitoring/recording	Monitoring must be conducted each season.

QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	NC_{OF}
Data unit	t N/t fertilizer
Description	Nitrogen content of organic fertilizer type *OF*
Equations	(21)
Source of data	Peer-reviewed published data may be used. For example, default manure N content may be selected from Edmonds et al. (2003) cited in US EPA (2021) or other regionally appropriate sources such as the European Environment Agency.
Description of measurement methods and procedures to be applied	See “Source of data.”
Frequency of monitoring/recording	Monitoring must be conducted each season. Parameter value must be updated when organic fertilizer product is changed or as new default values become available in peer-reviewed publications or databases.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	$M_{bsl,OF,i,t}$
Data unit	tonnes
Description	Mass of nitrogen-containing organic fertilizer type *OF* applied to quantification unit *i* in year *t* in the baseline scenario
Equations	(21)
Source of data	Management records from project area
Description of measurement methods and procedures to be applied	See Box 1.

Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	CR
Data unit	dimensionless
Description	Crop residue type
Equations	(21)
Source of data	Determined in quantification unit *i*
Description of measurement methods and procedures to be applied	See Box 1. Crop residue type is determined prior to verification.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	NC_{CR}
Data unit	t N/t dry mass
Description	Nitrogen content in dry mass of crop residue type *CR* (above- and belowground) before the rice season
Equations	(22)
Source of data	Peer-reviewed published data may be used.
Description of measurement methods and procedures to be applied	See “Source of data.”

Frequency of monitoring/recording	Monitoring must be conducted each season. Parameter value must be updated as new default values become available in peer-reviewed publications or databases.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	$M_{bsl,CR,i,t}$
Data unit	tonnes
Description	Total dry mass of crop residue returned to soils (aboveground and belowground) before rice season in quantification unit *i* in year *t* in the baseline scenario
Equations	(22)
Source of data	Management records from project area
Description of measurement methods and procedures to be applied	See Box 1.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	For all equations, the subscript *bsl* must be substituted by *wp* where the relevant values are being quantified for the monitoring period.

Data/Parameter	EF_{N2O}
Data unit	g N_2O/kg dry matter burned
Description	Nitrous oxide emission factor for the burning of rice straw
Equations	(23)
Source of data	Where no information source is available that is applicable to the project conditions, project proponents may define value from the most recent version of IPCC guidelines in Table 2.5 in Chapter 2, Volume 4 of IPCC (2019).

Description of measurement methods and procedures to be applied	IPCC (2019) default value: 0.07
Frequency of monitoring/recording	Source of data for the emission factor must be monitored every five years and must be updated when more accurate data applicable to the project conditions become available.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

Data/Parameter	$EF_{eu,r}$
Data unit	kg CO_2e/t dry rice straw
Description	Emission factor for rice straw for off-farm end use category *r*
Equations	(24)
Source of data	Project proponents must derive suitable values for $EF_{eu,r}$ using evidence including peer-reviewed literature, government records, production facility records, survey data, publicly available life cycle analysis databases, or reports compiled by industry associations.
Description of measurement methods and procedures to be applied	See guidance in Section 8.3.1.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	None

Data/Parameter	$RS_{removed,r}$
Data unit	t d.m.
Description	Mass of rice straw removed from field and sent to end use category *r*
Equations	(24)

Source of data	See guidance in Section 8.3.1.
Description of measurement methods and procedures to be applied	See guidance in Section 8.3.1.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	None

Data/Parameter	$Q_{N,i}$
Data unit	kg N/ha
Description	Application rate of nitrogen input for quantification unit *i* in the project scenario
Equations	(25)
Source of data	Fertilizer application log books from farmers, surveys among farmers
Description of measurement methods and procedures to be applied	See Box 1.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	Consolidated purchase receipts may be used to check N inputs.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	None

Data/Parameter	$M\_OA_{wp,l,t}$
Data unit	tonnes
Description	Mass of organic amendment (from livestock type *l*) applied as fertilizer in the project area in year *t*
Equations	(26)

Source of data	Management records from project area
Description of measurement methods and procedures to be applied	For manure application, data should be disaggregated for each livestock type *l*.
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of leakage
Calculation method	N/A
Comments	None

Data/Parameter	$CC_{wp,l,t}$
Data unit	t C/t organic amendment
Description	Carbon content of organic amendment applied as fertilizer in the project area in year *t*, disaggregated by livestock type *l* for manure
Equations	(26)
Source of data	See Box 1.
Description of measurement methods and procedures to be applied	For manure application, data should be disaggregated for each livestock type *l*.
Frequency of monitoring/recording	Monitoring must be conducted every five years or prior to each verification event where verification occurs more frequently.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of leakage
Calculation method	N/A
Comments	None

Data/Parameter	P_{wp}
Data unit	output (e.g., kg)/ha
Description	Average rice yield during the monitoring period
Equations	(27)
Source of data	Farm productivity (e.g., yield) records

Description of measurement methods and procedures to be applied	Measured using locally available technologies (e.g., mobile weighing devices, commercial scales, storage volume measurements, fixed scales, weigh scale tickets)
Frequency of monitoring/recording	Monitoring must be conducted each season.
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of leakage
Calculation method	N/A
Comments	None

Data/Parameter	RP_{wp}
Data unit	output (e.g., kg)/ha
Description	Average regional rice yield during the monitoring period
Equations	(28)
Source of data	Regional productivity data from government (e.g., USDA Actual Production History data), industry, published, academic, or international organization (e.g., FAO) sources
Description of measurement methods and procedures to be applied	N/A
Frequency of monitoring/recording	Every 10 years
QA/QC procedures to be applied	Guidance provided in IPCC (2003) Section 5.5 or IPCC (2000) Chapter 8 must be applied.
Purpose of data	Calculation of leakage
Calculation method	N/A
Comments	None

Data/Parameter	h
Data unit	dimensionless
Description	Stratum identifier
Equations	(35), (36)
Source of data	Determined in project area

Description of measurement methods and procedures to be applied	Project fields are grouped by cultivation pattern; stratum *h* covers all project fields with the same cultivation pattern.
Frequency of monitoring/recording	Monitoring must be conducted annually or prior to each verification event where verification occurs more frequently.
QA/QC procedures to be applied	None
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	None

9.3 Description of the Monitoring Plan

Ongoing monitoring of project activities is required to ensure accurate and conservative estimates of project emission reductions. While project activities are primarily implemented during the rice cultivation period, parameters must be monitored continuously during the whole year, including pre- and post-cultivation period.

Where possible, project proponents should employ digital monitoring, reporting, and verification (DMRV) tools – in particular remote sensing – to enable efficient third-party validation and verification of project data. Appendix 4 provides guidance on best practices for utilizing DMRV for projects developed under this methodology.

Where discretion exists in the selection of a value for a parameter, the principle of conservativeness must be applied (see the most recent version of the *VCS Standard*).

All projects must meet the requirements in Section 3.19 of the *VCS Standard, v4.7* (or equivalent section in the most recent version) with respect to environmental impacts. Examples of potential negative environmental impacts of projects include harm to migratory bird populations associated with reductions in winter flooding and challenges associated with the introduction of genetically modified organisms.

9.3.1 Monitoring Plan

The main objective of monitoring is to quantify emissions of CO_2, CH_4, and N_2O resulting from the monitoring period during the verification period.

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:

1) Description of each monitoring task to be undertaken, and the technical requirements therein

2) Definition of the accounting boundary, spatially delineating any differences in the accounting boundaries and/or quantification approaches
3) Parameters to be measured, including any parameters required for the selected model (additional to those specified in this methodology)
4) Data to be collected and data collection techniques and sample designs for directly sampled parameters (for additional guidance see Appendices 1 and 2)
5) Ten-year baseline re-evaluation plan, detailing source of regional (sub-national) agricultural production data and procedures to revise[31] the baseline schedule of activities
6) Quality assurance and quality control (QA/QC) procedures to:
    a) ensure accurate data collection.
    b) screen for, and where necessary, correct anomalous values.
    c) ensure completeness.
    d) perform independent checks on analysis results.
    e) provide other safeguards as appropriate.
7) Data archiving procedures, including procedures for any anticipated updates to electronic file formats. All data collected as a part of monitoring, including QA/QC data, must be archived electronically and kept for at least two years after the end of the last project crediting period.
8) Roles, responsibilities, and capacity of monitoring team and management
9) Modeling plan, where Quantification Approach 1 is applied. The project modeling plan must describe:
    a) the model(s) selected.
    b) the datasets used for model validation and calibration, including their sources.
    c) the baseline schedule of rice cultivation activities for each quantification unit (fixed ex-ante).

It is expected that management data is collected across all project fields within the quantification units in the project area according to the hierarchy outlined in Box 1, and as such sampling error does not factor into uncertainty deductions. However, where management data cannot be collected across the entire project area, sampling error must be accounted for. Where management data cannot be collected across all project fields, project proponents must justify the selected approach to collect data and follow guidance from the most recent version

[31] Applicable to projects seeking crediting period renewal

of the CDM guidelines *Sampling and Surveys for CDM Project Activities and Programmes of Activities*.[32]

9.3.2 Training and Technical Support

The project proponent must provide training and technical support to deliver appropriate information and guidance to the farmer in field preparation, irrigation, drainage, use of fertilizer, data collection, and other project implementation and monitoring requirements. Such support must be documented in a verifiable manner at both validation and verification (e.g., training protocol and documentation of on-site visits).

The training provided to project implementation staff and farmers must include training specific to the eligible project activities being employed. Training must, at a minimum, cover all of the eligible activities employed by the project and must provide holistic agronomic guidance regarding the new cultivation system being deployed. For example, where a new cultivar is introduced as part of the project, guidance must be given regarding any unique requirements for optimum cultivation of the new cultivar.

9.3.3 Implementation of AWD

When implementing AWD as a project activity, project proponents must use the services of professional experts with suitable qualifications and/or agronomic experience to develop criteria specific to each stratum and/or rice variety with respect to the recommended depth and duration for AWD drainage events. In developing guidance for the project farmers, the expert must take into account the critical goal of ensuring yield does not decline by more than 5% as a result of implementing the AWD activities. Where it is recommended by the expert that a region of the project should employ AWD to a depth of less than 10 cm below the soil level, the project must use Quantification Approach 2 for any such areas of the project. Note that where QA2 is applied, it is still necessary to ensure all project farmers are following the agronomic guidance provided by the project proponent with respect to the appropriate depth and duration of drainage specific to their strata. With respect to the timing of when AWD events are to occur, it is recommended, but not required, that farmers undertake their first AWD drainage event at least 21 days after the initial flood to ensure the pre-flood N application has time to be absorbed and is not washed away.

[32] Available at: https://cdm.unfccc.int/sunsetcms/storage/contents/stored-file-20151023152925068/Meth_GC48_%28ver04.0%29.pdf

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APPENDIX 1: STRATIFICATION OF THE PROJECT AREA AND ESTABLISHMENT OF QUANTIFICATION UNITS

Stratification of the project area is required to group fields into quantification units with homogenous cultivation patterns; each group is a stratum. The characterization of cultivation patterns must contain data on the parameters set out in Table 5. Under Quantification Approach 2, project proponents must also identify sites used as control sites (e.g., baseline control site and sample units) for gas chamber measurements in situ.

The stratification of the project area must follow the steps below.

Step 1: Characterization of cultivation pattern(s) in the baseline scenario

Gather data on historical practices for each field included in the project for all mandatory parameters listed in Table 5. The data collected to establish the schedule of activities (see Section 6, Table 3) should fulfill most of these data needs. However, the project proponent must collect data on any additional parameters listed in Table 5 that are not included in the schedule of activities to ensure a complete set of mandatory parameters (and optional parameters, where selected).

Step 2: Characterization of cultivation pattern(s) in the project scenario

Describe all planned project activities for each field included in the project for all mandatory parameters listed (and optional parameters, where selected) in Table 5.

Step 3: Identification of strata

Group project fields based on homogeneous cultivation patterns; each group is a stratum.

For the purposes of determining baseline scenario and project activity emission factors, project proponents must define representative fields from which data must be used for quantification of reductions (Section 8).

Table 5. Guidance for the identification of cultivation patterns for stratification of the project area

Parameter	Type	Category	Optional/Mandatory for Stratification
Water regime – on-season	Dynamic[1]	Continuously flooded	Mandatory
		Single drainage	
		Multiple drainages	
	Dynamic	Flooded	Mandatory

Parameter	Type	Category	Optional/Mandatory for Stratification
Water regime – pre-season		Short drainage (<180 days)	
		Long drainage (>180 days)	
Organic amendment (application rate)[2]	Dynamic	No organic amendment	Mandatory
		Low, medium, to high organic amendment	
Organic amendment (type)[3]	Dynamic	Straw on-season (mulch)	Mandatory
		Green manure	
		Straw off-season	
		Farmyard manure	
		Compost	
		No organic amendment (only low volume of rice stubble is left after harvesting or straw is burned)	
Biochar[4]	Dynamic	Any volumes of biochar added to soils where rice is cultivated in the project	Mandatory
Methanotrophs[4]	Dynamic	Any volumes of methanotrophs added to soils where rice is cultivated in the project	Mandatory
Cultivation period	Dynamic	Cultivar-dependent	Mandatory
Nitrogen fertilizer application	Dynamic	<100 kg N/ha 100–200 kg N/ha 200–300 kg N/ha >300 kg N/ha	Mandatory/Optional[5]
Soil pH	Static[6]	<4.5	Optional
		4.5–5.5	
		>5.5	
Soil texture	Static	Average soil texture within a stratum must be in the same FAO soil textural class[7]	Optional
Soil organic carbon	Static	<1%	Optional
		1–3%	
		>3%	
Climate	Static	Agro-ecological zone	Optional

1: Dynamic conditions are subject to changes over time whether due to management or other reasons (e.g., climatic conditions such as droughts events).

2: Where different rates of organic amendments are applied, project proponents must take the most conservative approach to quantifying GHG emissions (e.g., taking field CH_4 measurements for calculating the total GHG balance under QA2 at the field that receives the higher application rate).

3: Where the project includes two or more types of organic amendment and/or application rates for straw amendment, a single stratum may be set based on the most conservative organic amendment (i.e., the lowest organic amendment rate) instead of setting multiple strata.

4: Where any biochar or methanotrophs are added to rice farms in the project, such application must be taken into account when stratifying for QA2.

5: Where a project activity involves changes in nitrogen management, nitrogen fertilizer application is a mandatory parameter for stratification. Otherwise, N application rate is an optional parameter for stratification.

6: Static conditions are site-specific parameters less prone to changes over time and thus initially must be determined only once for a project and the corresponding fields (i.e., for baseline assessment).

7: See Annex 4 in the *FAO World Reference Base for Soil Resources 2014*, available at: https://www.fao.org/3/i3794en/I3794en.pdf

APPENDIX 2: GUIDELINES FOR FIELD MEASUREMENTS UNDER QUANTIFICATION APPROACH 2

Direct measurements must be taken annually and at every cultivation period when applying Quantification Approach 2. Calculation of emission factors must be seasonally integrated (see Section 8.2.4).

A detailed measurement plan must be developed that includes at least the following elements:

1) Detailed description of the process adopted for stratification of the project area (see guidance in Appendix 1)

2) Description of the planned sampling approach and schedule for field chamber measurements including logistics necessary to transport the gas samples from the field to the laboratory

3) Description of the laboratory gas analysis (i.e., gas chromatography) technique, equipment, and schedule

4) Cropping calendar reference information for selection of the measurement sites at which gas chamber measurements will take place

The project proponent must ensure that the sampling and analysis protocol is optimized for rice systems, including any necessary adjustments (e.g., corrections for interferences due to air moisture and ambient concentrations of the tested gases). Project proponents must report minimum detection levels and ensure that standard gas mixtures used to calibrate/validate equipment span the detected concentration ranges.

Methane measurements must be taken at sites that represent the cultivation pattern of the baseline scenario (i.e., baseline control sites) and project activity (i.e., sample units). A project must have at least three baseline control sites and three sample units per stratum. For each sample point, either a separate chamber must be used, or chambers may be moved around between sample points for each measurement event. For each gas chamber, three samples at three time intervals (e.g., t_0, $t_{15'}$, $t_{30'}$) must be taken per measurement event (i.e., three samples from each chamber, at each sample point). Therefore, a project employing a single stratum with a single consistent deployment of practices (e.g., AWD is implemented across the entire project and all fields have the same historic cultivation pattern representing the baseline scenario) would have a minimum of 18 gas samples taken per measurement event: nine gas samples from three measurement sites representing the project activity and nine gas samples from three measurement sites representing the baseline scenario.[33]

The implementation of direct measurements must involve suitably qualified and experienced staff, which may include third parties (e.g., independent consultants, members of research institutions) and/or qualified staff of the project itself, to design and implement the direct measurement campaign. The guidelines in this appendix do not replace the expertise required in implementing direct measurements using gas chambers.[34] Instead, it provides minimum requirements and additional recommendations.

Table 6 details the options for gas chamber equipment and Table 7 details the sampling requirements for field measurements. Records must be kept demonstrating the timing of each sample and the relevant management practices being deployed in each sample location. All sampling activities must be carried out by individuals with suitable training and experience in undertaking such sampling.

Table 6. Technical options for gas chamber design

Feature	Conditions	
Chamber material	**Option 1: Non-transparent** • Commercially available polyvinyl chloride (PVC) containers or manufactured chambers (e.g., using galvanized iron) • Painted white or covered with reflective material (to prevent increasing inside temperature) • Only suitable for short-term exposure (typically 30 min) followed by immediate removal from the field	**Option 2: Transparent** • Manufactured chambers using acrylic glass • Can be placed for longer time spans in the field where equipped with a lid that remains open between measurements and is only closed during measurements
Placement in soil	**Option 1: Fixed base** • Base made of non-corrosive material and remains in the field for the whole season • Base should allow tight sealing of the chamber • Base should have bores in the submerged section to allow water exchange between inside and outside	**Option 2: Without base** • Chambers must be placed on the soil with open lid to allow escape of eventual ebullition

[33] Minamikawa et al. (2015, p. 8)

[34] Expert guidance on gas sampling can be found in peer-reviewed literature, including Minamikawa et al. (2015, 2018) and Tiwari et al. (2015) and online at US ARS GraceNet Sampling Protocol https://www.ars.usda.gov/anrds/gracenet/gracenet-protocols/ and IRRI https://ghgmitigation.irri.org/resources/guidelines/measurements-approaches/manual-chamber-method

Feature	Conditions	
	• Base should be installed at least 24 hours before the first sampling	
Auxiliaries of chamber	• Thermometer for measuring the temperature inside the chamber • Fan (battery-operated) inside the chamber for mixing air inside the chamber during sampling • Sampling port (rubber stopper placed in a bore of the chamber)	
Basal area	Rectangular or rounded, but has to cover minimum of four rice hills (approximately 0.1 m^2 minimum)	
Height	**Option 1: Fixed height** • Total height (protruding base + chamber) should exceed plant height	**Option 2: Flexible height** • Adjustable to plant height • Chambers with different heights or modular design

Table 7. Summary of field direct measurement requirements

Element	Requirement
Sample points per strata	Baseline emissions: at least three Project emissions: at least three
Number of gas samples per chamber	At least three per exposure
Measurement duration (exposure time)	Sample within 30 minutes of placing the top of the chamber onto the frame in the ground
Sample time of day	Between 09:00 am and 12:00 pm All samples in the given strata must be sampled within three hours of the first sample being taken.
CH_4 sampling frequency	Minimum requirement: once per week, during cultivation period
Duration of CH_4 sampling regime	Commencing at first flooding, continuing until the first significant fallow for each cultivation period
Gas sample collection or temporary storage using syringe	Suitability test (leakproof) before measurement Preferably equipped with a lock (two- or three-way) for ease of handling
Sample storage until analysis	Storage <24 h: air samples may remain in syringe Storage >24 h: transfer air samples into evacuated vial, store with slight overpressure

Table 8 details the requirements for laboratory gas analysis. Gas analysis must be undertaken by a qualified laboratory using commercial equipment, by individuals with suitable training and experience in undertaking such analysis.[35] The vials containing the gas sample must be transferred to the laboratory for analysis as soon as possible after each sampling event. The procedures for handling vials, from initial sampling through until the gas analysis is complete, must be documented and reported. All gas analysis equipment must be maintained and calibrated per the manufacturer's specifications and calibrated before every analysis using certified standard gases.[36]

Table 8. Summary of laboratory analysis requirements

Feature	Conditions
Method	Gas chromatograph with flame ionization detector (FID)
Injection	Direct injection or with multi-port valve and sample loop
Column	Packed (e.g., molecular sieve) or capillary column
Calibration	With certified standard gas each day of analysis before and after the analyses are completed
Accreditation	Where possible, the selected analytical laboratory should be ISO/IEC 17025 accredited.[37]

[35] *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, Chapter 5, Box 5.2A (New)

[36] Ibid.

[37] The selection of an analytical laboratory should be based on its listing as an approved analytical service provider of environmental greenhouse gas (e.g., CH_4) measurements according to national and/or international standards/accreditation.

APPENDIX 3: N_2O CORRECTION FACTOR

All fields that employ changes in irrigation (from continuous flooding to single or multiple drainage) must account for N_2O emissions associated with such changes by applying an N_2O correction factor (CF_{N2O}: 0.00314 kg N_2O/kg N), irrespective of whether there are any changes in rates of N fertilizer applied. The N_2O correction factor has been derived from the emission factors for flooded rice fields (EF_{1FR}) Table 11.1 (Updated) in Chapter 11, Volume 4 of the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. The difference between the aggregated default value emission factors for continuously flooded rice fields (0.004 kg N_2O/kg N) and rice fields with single or multiple drainages (0.005 kg N_2O/kg N) was converted from N_2O-N into N_2O emissions using the emissions factor for N_2O-N to N_2O. Table 9 demonstrates the values used in the calculation and the approach. All emission factor values in the table below are taken from Table 11.1 (Updated) in Chapter 11, Volume 4 of the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Table 9. Values used in calculation of the N_2O correction factor (adapted from IPCC 2019)

Emission Factor (EF)	Aggregated		Disaggregated		
	Default Value	Uncertainty Range	Disaggregation	Default Value	Uncertainty Range
EF_1 for N additions from synthetic fertilizers, organic amendments, and crop residues, and N mineralized from mineral soil as a result of loss of soil carbon (kg N_2O-N/kg N)	0.01	0.002–0.018	Synthetic fertilizer inputs[1] in wet climates	0.016	0.013–0.019
			Other N inputs[2] in wet climates	0.006	0.001–0.011
			All N inputs in dry climates	0.005	0.000–0.011
EF_{1FR} for flooded rice fields[3] (kg N_2O-N/kg N)	0.004	0.000–0.029	Continuous flooding	0.003	0.000–0.010
			Single and multiple drainage	0.005	0.000–0.016
$EF_{3PRP,CPP}$ for cattle (dairy, non-dairy, and buffalo), poultry, and pigs (kg N_2O-N/kg N)	0.004	0.000–0.014	Wet climates	0.006	0.000–0.027
			Dry climates	0.002	0.000–0.007
$EF_{3PRP,SO}$ for sheep and “other animals” (kg N_2O-N/kg N)	0.003	0.000–0.010	-	-	-

Disaggregation of EF_1 and $EF_{3PRP,CPP}$ by climate (based on long-term averages): Wet climates occur in temperate and boreal zones where the ratio of annual precipitation to potential evapotranspiration is greater than 1, and tropical zones where annual precipitation is greater than 1000 mm. Dry climates occur in temperate and boreal zones where the ratio of annual precipitation to potential evapotranspiration is less than 1, and tropical zones where annual precipitation is less than 1000 mm. Figure 3A.5.1 in Chapter 3, Vol. 4 in IPCC (2019) provides a map subdividing wet and dry climates based on these criteria. In wet climates, EF_1 is further disaggregated by synthetic fertilizer N inputs and other N inputs.

1: This emission factor should be used for synthetic fertilizer applications and fertilizer mixtures that include both synthetic and organic forms of N.

2: Other N input refers to organic amendments, animal manures (e.g., slurries, digested manures), N in crop residues, and mineralized N from soil organic matter decomposition.

3: Disaggregation of EF_{1FR}: Single and multiple drainage also includes alternate wetting and drying. Disaggregated EF_{1FR} for rain-fed and deep-water systems is not provided due to lack of data.

EF_1: Uncertainty range of disaggregated EF_1 based on the 95% confidence interval of fitted values. Uncertainty range of aggregated EF_1 is based on the 2.5th to 97.5th percentile of the dataset.

EF_{1FR}, $EF_{3PRP,CPP}$, and $EF_{3PRP,SO}$: Uncertainty ranges are based on the 2.5th to 97.5th percentile.

For EF_2, see guidance in *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, Chapter 2, Table 2.5.

APPENDIX 4: GUIDANCE FOR DIGITAL MONITORING, REPORTING, AND VERIFICATION (DMRV)

Under this methodology, project proponents are encouraged to employ digital monitoring, reporting, and verification (DMRV) tools, in particular remote sensing, to efficiently enable third-party validation and verification of project data. This appendix provides guidance with respect to best practices for using DMRV for projects developed under this methodology.

Table 10. Guidance for quality assurance and quality control (QA/QC) best practices for use of DMRV

DMRV Type	Issue	Guidance	Example Use
Remote sensing (RS)	Temporal/spatial resolution	Consider setting a minimum spatial and temporal resolution, differentiated based on the intended use.	A project proponent uses RS to detect irrigation events. The project proponent ensures satellite image frequency is high enough to capture the typical and/or expected dry period duration for project farmers. The project proponent employs the use of satellite imagery with 2–4-day frequency around expected irrigation events, as they know that the farmers typically dry their fields for 4–5 days.
	Bands/types of data	Consider setting requirements for bands and types of data, differentiated based on intended use.	A project proponent uses radar to detect moisture levels in the soil. The project proponent deploys different wavelengths depending on seasonal timing. This ensures that as the crop matures and the canopy closes over the ground, obstructing view of the soil, the wavelength chosen for latter parts of the season can penetrate the canopy and effectively determine soil moisture.
	Correction	Remote sensing data should be corrected to surface reflectance units (atmospheric correction) and filtered for clouds and cloud shadows. Consider limiting the amount of correction that may be applied to a single scene.	A project proponent uses three separate satellite datasets. For one drying event on a specific field, the satellite feeds from all three datasets are partially covered by clouds. The project proponent determines that correcting all three available data feeds would be excessive, and therefore determines not to use any such data to determine

DMRV Type	Issue	Guidance	Example Use
			values for that parameter. The project proponent documents this and uses alternative data for this parameter value.
	Verifiability	Only use publicly available RS datasets or ensure all proprietary RS data are made available to the VVB to enable them to validate/verify work undertaken.	A project proponent uses a combination of public and proprietary RS datasets and provides the VVB access to their GIS-enabled platform, enabling the VVB to undertake spot checks.
		Project proponents should only use RS to create data that can be independently verified.	A project proponent uses RS to demonstrate fields were double cropped. The project employs a GIS-enabled platform and allows the VVB access, enabling the VVB to have an efficient means to validate historical and contemporary double cropping via remote desktop audits.
Machine learning / artificial intelligence (ML/AI)	Features	Project proponents should report on their feature set and explain how each feature is relevant to the task at hand. Such data may be marked as confidential, in which case it will not be made publicly available but will be available to the VVB and Verra.	A project proponent reports on their ML/AI model feature set, provides the VVB with a summary description of how the model uses such features, and gives the VVB opportunities to test the model and ask questions regarding how it works. This ensures the system is not a “black box,” enabling more effective validation and verification of its use.
	Validation	Project proponents should validate ML/AI model results against independent ground truth data, using either cross-validation (preferably spatial rather than random) and/or independent holdout datasets.	A project proponent provides the VVB and Verra with an analysis of how the model was validated, as an additional layer of assurance.
	Verifiability	Project proponents should only use ML/AI to create data that can be independently verified.	A project proponent uses an ML/AI model to create digital maps of project areas and estimate field size. VVBs can then independently use RS software (such as Google Earth) to estimate field size, as well as review other datapoints from the project, and then use these to validate the ML/AI model outputs.
		Project proponents should identify clear means to test their ML/AI tools, to facilitate VVB spot-checking.	A project proponent provides the VVB access to their GIS-enabled platform, enabling the VVB to undertake spot checks of any farm against other datasets provided by the project

DMRV Type	Issue	Guidance	Example Use
			proponent, publicly available data, and other data gathered by the VVB.
All DMRV systems	Ground truthing	Project proponents should compare data from multiple sources (as outlined in Box 1), including: • farmer logbooks. • literature and/or government/public datasets. • remote sensing data.	A project proponent uses digital farmer logbooks to capture data for the full schedule of activities. RS tools are then used to verify many of the most critical datapoints, such as confirming rice was grown, field preparation dates, irrigation dates, dry period dates and duration, harvest date, and burning of rice straw. The project proponent makes all data and the GIS-enabled tool available to the VVB to perform independent spot checks at the VVB's discretion.
	Ground truthing	Project proponents should: 1) create typical value ranges for key parameters (e.g., using literature, government/public datasets) and flag any significant deviation from the range. 2) create a clear process to be followed to detect and address deviations, and record any/all changes to project data. 3) consider disallowing use of data outside the given ranges unless justification is given. 4) retain all information regarding such QA/QC measures, including their Standard Operating Procedure (SOP) for such issues, summary of ranges, summary of all data inputs outside of range, summary of any interactions between relevant parties regarding flagged data, summaries of any changes to data, and should make all such data available to the VVB and Verra.	A project proponent captures primary data using a farmer logbook, and compares such data against a typical range for the given parameter. Any significant deviation from the range is flagged by the project proponent and project implementation staff are required to provide rationale for why the value is outside of the expected range. Where the project proponent determines that a sufficient explanation has been given, the out-of-range value is adopted. Otherwise the out-of-range value is substituted with the most conservative value within the given pre-determined range. The decision made by project staff is documented. The VVB is presented with all requisite data.

DMRV Type	Issue	Guidance	Example Use
	Data integrity	An SOP should be created to handle data for each project. This should clearly identify how data are captured and moved between various systems, and whether, when, by whom, and how such data has been altered since being ingested into project digital systems. Such systems should be auditable and should be made available to the VVB and Verra.	A project proponent makes all suggested data available to the VVB. This enables the VVB to understand the project's data architecture and flow of data through the systems and into the project documentation. The VVB can then undertake spot checks, choosing certain farms and tracing raw data through the systems, confirming the project proponent followed the SOP, and confirming the results appear reasonable in the circumstances.
	Validation of accuracy of digital analysis	Project proponents using DMRV should provide some analysis of the accuracy/error rates of the digital systems they are deploying. Project proponents should consider developing an error threshold for their systems, and a rule whereby they would replace any data that fails to meet such thresholds.	A project proponent outsources DMRV to a third-party software provider. The third-party software provider uses an RS-informed, GIS-enabled software tool. The third-party software provider undertakes their own validation and has a threshold of 80% accuracy, whereby they test specific analysis functions and only use them where the system performs with an 80% accuracy rate. Any specific data point which is found to fail the threshold is also discarded, and the project proponent is directed to use alternative data points for the given parameter.

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