T-VER-P-METH-13-08

Enhanced Good Practices in Paddy Rice Field

Version 01

Sector: 15 –Agriculture

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1. Methodology Title	Enhanced Good Practices in Paddy Rice Field
2. Project Type	Reduction, absorption and removal of greenhouse gases from the forestry and agriculture sectors
3. Sector	15 - Agriculture
4. Project Outline	Greenhouse gas emission reduction from enhanced good practices in paddy rice field
5. Applicability	1. Project area has land-use rights certificate as specified by law. 2. Good management in rice cultivation must contain one of the following criteria: a. The land must apply adjusted water management practice. b. The land must reduce the use of nitrogen fertilizers.
3. Project Conditions	1. Project area may consist of multiple areas grouped together. 2. The area is suitable with its designated land use zoning. 3. Not at risk of land slide. 4. In the case of adjusted water management practice in rice cultivation, the project area must be located within irrigated zones or areas with self-supplied water resources. Farmers must also provide equipment or tools that allow for effective control of irrigation and drainage.
4. Project start date	The date on which project activities commence on the project land, or the start date of the cropping season during which the project activities are implemented.
5. Remarks	-

Definitions

Term	Definition
Adjusted water management practices	Adjusted water management practices in rice cultivation can be categorized into pre-season and on-season practices. Pre-season water management includes a shortened period of flooded condition prior to planting. During the cultivation period, water management practices involve a shortened period of continuous flooding, shifting to intermittent flooding, and adopting alternate wet and dry (AWD) rice cultivation methods.
Appropriate fertilizer management	Appropriate fertilizer management refers to considering the rate, form, timing, and placement of fertilizer application in accordance with scientific fertilizer application guidance. This includes: 1) Optimizing the application rate of fertilizer to match the nutrient requirements of crops and current supply of nutrients in the soil. 2) Selecting fertilizer forms that minimize nutrient losses and are accessible to farmers. 3) Optimizing fertilizer application methods and timing, such as applying fertilizers in areas readily accessible for plant uptake and at times when the crops need them most. Specifically, (1) the application rate of chemical fertilizers containing nitrogen must be reduced by at least 5% compared to the baseline scenario; and (2) the use of organic fertilizers in flooded rice fields should be appropriately managed to avoid increased methane emissions. For example, the incorporation of organic materials into paddy fields followed by a minimum aerobic decomposition period of 14 d prior to the initiation of flooding. These practices should be based on scientific guidance.
Water drainage or drying of rice fields	**Intermittently flooding (single drainage):** Fields have a single aeration by water drainage or field drying during the cropping season. This practice involves either allowing the field to dry to soil surface or below, without adverse effects on rice growth or yield. Fields may only dry for harvest (except for end-season drainage). **Intermittently flooding (multiple drainage):** Fields have more than one aeration period by water drainage or field drying during the cropping season and may only dry for harvest (except for end-season drainage). AWD method is also included. This practice requires the field to dry to soil surface or below, without adverse effects on rice growth or yield. A

Term	Definition
	dry condition is defined as a water level that falls 10–15 cm below the soil surface, or as otherwise recommended by relevant scientific guidance.
Chemical fertilizer	A fertilizer derived from inorganic substances or synthetic organic compounds. This includes straight fertilizers, compound fertilizers, complex fertilizers, and organic–chemical fertilizers. These fertilizers contain essential macronutrients such as nitrogen (N), phosphorus (P), and potassium (K).
Organic fertilizer	A fertilizer derived from organic materials that have been processed through methods such as moistening, chopping, composting, grinding, sieving, or extraction and have undergone complete microbial decomposition. It does not include chemical fertilizers or biofertilizers
Biofertilizer	A substance that contains living microorganisms capable of producing nutrients or enhancing nutrient availability to plants. It is used to improve soil quality through biological, physical, or biochemical processes. The term also includes microbial inoculants or starter cultures used for this purpose.
Organic-chemical fertilizer	A fertilizer that contains guaranteed amounts of nutrients with a minimum level of organic matter as stipulated by the Ministry of Agriculture and Cooperatives.
Compost	An organic fertilizer derived from the decomposition of plant residues, agricultural waste, or industrial by-products, which are composted through microbial activity—often in combination with animal manure or microbial inoculants—to facilitate the breakdown of organic matter.
Farmyard manure	An organic fertilizer derived from the excreta of various animals, in both solid and liquid forms. It can be applied directly as fresh or dried manure, or it may be composted to allow for the decomposition of animal waste before use.
Green Manure	An organic fertilizer consisting of growing plants that are incorporated into the soil.
Legal Land Use Rights Certificate	Documents demonstrating ownership of land, rights to use the land according to the law, such as a land title deed (Nor Sor 4), a certificate of utilization (Nor Sor 3), a document on land use rights in land reform area (Sor Por), a request for public use, letter of permission to use in the self-establishing industrial estate (Nor Khor 3) or land utilization certificate from the relevant government agency

In addition to the definitions contained in this document, use definitions consistent with definitions in the T-VER, CDM and IPCC Guidelines.

T-VER Methodology for Enhanced Good Practices in Paddy Rice Field

1. Scope of project

1.1 Operation Characteristics

Assessment methods to enhance good practices in paddy rice fields include detailed calculations of greenhouse gas (GHG) emission reductions and the implementation of good agricultural practices, with a focus on promoting methane (CH_4) reduction through adjusted water management, and net reductions of nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions through fertilization practices adopted by farmers. The activities involved in project implementation are important to the project's GHG emission reduction capabilities as follows:

1) Project development must undertake at least one of the following:
   - Adjusted water management practices include shortening the duration of flooded conditions, shifting from continuous to intermittent flooding during the cultivation period, adopting AWD techniques, and reducing the flooding period during the pre-season water regime.
   - Reducing nitrogen fertilizer use, e.g., appropriate application rates, forms, frequency and timing (lowering overall input), applying nitrogen transformation inhibitors (nitrification inhibitors and urease inhibitors).

2) In the case of adjusted water management practice in rice cultivation, farmers must provide equipment or tools that allow for effective control of irrigation and drainage.

3) The project must provide training and technical support for participating farmers to delivers appropriate knowledge in field preparation, irrigation, drainage and use of fertilizer. Documentary evidence of these activities must be provided. In addition, the project participant must ensure that farmers have adequate knowledge and understanding of GHG mitigation practices and are capable of implementing the monitoring and implementation plan as specified.

4) Project activities must not reduce more than 5% of agricultural productivity as assessed by experts and/or information from publications conducted in the same or comparable region. In cases where agricultural yield is reduced by more than 5% but not exceeding 15%, the project participant may submit reasonable supporting documents to justify the exclusion of leakage consideration from agricultural production. This is due to the inherent variability in tropical climates and the sensitivity of agricultural yields in Thailand to climatic conditions *(based on agricultural production data from the Office of Agricultural Economics).* Such variability may significantly affect crop yields and, consequently, the outcomes of project implementation.

1.2 Project Boundary

The project participant must identify project location including geographic coordinate, location, and other details of such location as well as a legal land rights or land use certificate.

2. Selection of emission source and GHG type for calculation

Source	GHG	Included	Explanation
Baseline Emission			
Liming	CO_2	Conditional*	The application of lime materials containing carbonates contributes to carbon dioxide emission from the soil
Urea Fertilization	CO_2	Conditional*	Urea fertilization contributes to carbon dioxide emission from the soils
Soil Methanogenesis	CH_4	Conditional*	Emission resulting from the anaerobic decomposition of organic carbon in the soil.
Use of Nitrogen Fertilizers	N_2O	Conditional*	Emission resulting from nitrogen fertilizer application
Project Emission			
Liming	CO_2	Conditional*	The application of lime materials containing carbonates contributes to carbon dioxide emission from the soil
Urea Fertilization	CO_2	Conditional*	Urea fertilization contributes to carbon dioxide emission from the soils
Soil Methanogenesis	CH_4	Conditional*	Emission resulting from the anaerobic decomposition of organic carbon in the soil.
Use of Nitrogen Fertilizers	N_2O	Conditional*	Emission resulting from nitrogen fertilizer application

Source	GHG	Included	Explanation
Fossil Fuel Combustion	CO_2	Conditional*	Emission resulting from the use of additional machinery or equipment beyond current practices, due to energy consumption from fossil fuels or electricity
Biomass Burning	CH_4	Conditional*	Emissions resulting from the open burning of crop residues, e.g., rice straw and stubble, in the project area
	N_2O	Conditional*	

Remark * Conditional = Assessment is conducted when project activities may cause GHG emissions to increase or decrease by at least 5% compared to the baseline scenario. *T-VER-P-TOOL-01-09 Tool for Testing Significance of GHG emissions in Project Activities* may also be used for this assessment.

3. Baseline scenario

The calculation of GHG emission reductions must reflect actions that go below business-as-usual (BAU)[1] practices. Therefore, the baseline emissions assessment should estimate emissions lower than those under normal operations. This methodology applies the principle of historical emissions adjusted downwards specifically for agricultural practices with primary GHG mitigation potential, such as adjusted water management practices in rice cultivation. Other GHG reduction activities, e.g., fertilizer application, are not subject to this adjustment requirement.

The project participant is required to determine representative or reference field conditions with detailed rice cultivation pattern for both the baseline and project emissions, as presented in Table 1.

Table 1 Details on agricultural practices for baseline and project emissions.

Parameter	Type[1]	Values/Categories	Explanation
Water regime (on-season)	Dynamic	• Continuously flooded • Intermittent flooded (single drainage) • Intermittent flooded (multiple drainage and AWD)	
Water regime (pre-season)	Dynamic	• Flooded pre-season >30 days	

Parameter	Type[1]	Values/Categories	Explanation
		• Non-flooded pre-season <180 days or short flooding <30 days • Non-flooded pre-season >180 days • Non-flooded pre-season >365 days or upland crop - paddy rotation	
Organic amendment	Dynamic	• No organic amendment • Straw incorporated shortly (<30 days) before cultivation • Straw incorporated long (>30 days) before cultivation • Green manure • Farmyard manure • Compost	
Soil pH	Static	<4.5 4.5-5.5 >5.5	* For approach 2: direct measurement
Application of chemical fertilizer	Static	• Chemical fertilizer applied • No chemical fertilizer applied	
Liming	Static	• Lime material applied • No lime material applied	
Soil organic carbon	Static	<1% 1-3% >3%	* For approach 2: direct measurement
Climate	Static	Agroecological zones (AEZ)	Classified by country region

Remark:

[1] *Dynamic conditions are those that are connected to the management practice of a field, thus can change over time and shall be monitored in the project fields. Static conditions are site-specific parameters that characterize a soil and do not (relevantly) change over time and thus do in principle only have to be determined once for a project and the corresponding fields.*

Data for the baseline scenario is obtained from farmers and assessed using historical cultivation records covering a period of no less than three years, or from published documents that are appropriate for the project area. The data should be in-line or be consistent with relevant documents, guidelines, or guidance from related agricultural organizations.

In selecting recommended data for the baseline scenario, the principle of conservativeness should be applied—specifically, selecting values that yield the lowest estimated GHG emissions. When baseline emissions are assessed using modeling approaches, it is necessary to conduct direct measurements at the project site at the initial stage or to reference data from local research studies. These data serve as initial inputs for the model.

In the case of project renewal crediting period, the baseline scenario must be reviewed and updated, along with other relevant parameters, in accordance with the latest version of the applicable methodology. However, if there is evidence demonstrating the continuity of agricultural activities, the original baseline may continue to be used in alignment with the previous cultivation practice pattern.

4. Additionality

Project participants must undertake the process of demonstrating additionality of the implemented activities, as follows:

- **Step 1:** The project participants shall demonstrate additionality by proving the project activity is additional to what is required by the law.
- **Step 2:** Prove activities that are not common practices.

  Enhanced good practices in paddy rice field—such as AWD, system of rice intensification, residue incorporation, and fertilizer application based on soil analysis are considered as additional agricultural practices that involve relatively complex procedures and additional operational details. Therefore, the implementation of such practices is classified as good agricultural practices and recognized as agricultural practices that are not common practices.

- **Step 3:** Identify the barriers that may hinder the transition from existing agricultural practices to improved methods.

  Project participants must demonstrate the existence of barriers that prevent the adoption of low GHG agricultural practices. These barriers may include financial constraints, farmers' attitudes and openness to change, ecological limitations specific to the local environment, cultural traditions and social values, regulatory and legal restrictions, market-related challenges, and limitations in access to tools and technologies. The verification of obstacles may involve a single issue or multiple issues, depending on the conditions observed within the project area.

Once the project participant has completed steps 1 through 3 and the assessment results are consistent with the requirements, the project shall be considered to have additionality.

5. Quantification of GHG emission reductions

A quantitative assessment of GHG emission reductions from enhanced good practices in paddy rice fields involves the GHG calculations in baseline and project emissions. GHG emissions are quantified in terms of emission rate for methane, nitrous oxide, and carbon dioxide, expressed in metric tons of carbon dioxide equivalent (tCO_2eq) per unit area over the monitoring period. Subsequently, the total change in GHG emissions is assessed to determine the amount of emission reduction attributable to the project activities.

The approach for quantifying GHG emissions from enhanced good practices in paddy rice fields is categorized into three methods, as follows:

- **Assessment method 1: Modeling**

  Appropriate models for estimating GHG emission rates from agricultural land may range from empirical models to process-based models that comprehensively account for driving factors such as climate conditions, soil characteristics, soil carbon content, and agricultural practices. Project participants are required to conduct assessments in accordance with appropriate guidelines, including model calibration and validation. Detailed descriptions of the guidelines or methodologies applied at each stage of the assessment must be provided, with reference to internationally recognized guidelines.

  Model-based assessments for each sample unit under the baseline scenario are used to project changes or emissions resulting from agricultural practices conducted under baseline conditions. Typical input data for the model include soil organic carbon content, bulk density, other soil characteristics, and climatic variables such as rainfall and temperature. For project implementation, it is essential to monitor relevant data required as model inputs. Furthermore, the accuracy of the model used for projections must be demonstrated using appropriate validation techniques, such as correlation coefficients between observed and predicted values, or statistical indicators like the Root Mean Square Error (RMSE).

  The use of models to estimate GHG emissions from agricultural land—such as methane and nitrous oxide emissions from soil—does not necessarily require direct measurement of emissions within the project area. Instead, data on GHG emissions may be sourced from (1) experimental or research plots, or (2) scientific literature, such as peer-reviewed publications or reports. The selected reference data must be appropriate and applicable to the project area, particularly when aligned with relevant controlling factors or agricultural practices.

Guidance on model-based GHG emission assessments in agricultural systems are detailed in Appendix 3.

- **Assessment method 2: Direct measurement**

  This involves collecting and analyzing samples directly from the project area to generate data for direct measurement. Sampling must be conducted in both the baseline and project reference fields. Project participants are required to provide a detailed description of the assessment assumptions and methodologies applied at each stage, with reference to the guidelines established by the Thailand Greenhouse Gas Management Organization (TGO) or other internationally recognized standards.

- **Assessment method 3: Using defaults**

  This approach involves defining equations for calculating GHG emissions, based on internationally recognized assessment methodologies—particularly those outlined in national GHG inventory guidelines. The recommended hierarchy for selecting emission factors is presented as follows:

  (1) Emission factors specific to project area, derived from peer-reviewed scientific literature or developed using data collected from the project area, following Tier 2 methodologies as defined in the IPCC Guidelines, and reviewed by experts.

  (2) Emission factors from other reliable sources, such as national emission factors, data published by government agencies, or other peer-reviewed publications. These sources must be reviewed by experts to ensure the appropriateness of the emission factors used. Supporting evidence must be provided to demonstrate the reliability and relevance of the selected data sources.

  (3) Tier 1-default emission factors in the IPCC Guidelines

The agricultural practices within the project boundary of the enhanced good practices in paddy rice field are assessed according to the methodology outlined in Table 2.

Table 2 Summary of the applicable quantitative assessment approaches

GHG	Source	Assessment method 1: Modelling*	Assessment method 2: Direct measurement	Assessment method 3: Using defaults
CO_2	Fossil fuel			√
	Liming			√
	Urea fertilization			√
CH_4	Soil methanogenesis	√	√	√ (applicable only to small-scale and micro-scale projects**)
CH_4	Biomass burning			√
N_2O	Use of nitrogen fertilizers	√	√	√
	Biomass burning			√

Remark:

* *Assessment method 1 can be applied when an appropriate model is available. The guidance on evaluating the suitability of the model can be referenced from the guidelines on model calibration and validation, or other relevant sources.*

** *Small-scale and micro-scale projects must comply with the criteria set by TGO.*

5.1 Baseline emissions

The quantitative assessment of baseline GHG emissions for enhanced good practices in paddy rice fields requires data collection and the application of appropriate methodology as listed below:

Assessment method 1: Modelling

Baseline GHG emissions must be simulated for each designated sample unit. The model is used to project emissions based on rice cultivation practices carried out under baseline conditions. Recommended data for the model are outlined below:

- Soil organic carbon content and bulk density: These parameters are used to calculate the baseline soil carbon stock. Soil samples should be collected directly prior to the start of the project (at time t = 0), or may alternatively be based on measurements taken within five years before or after the project start date (at time t = ±5 years). Sampling and analysis methods should follow the procedures outlined in Appendix 3.
- Other soil characteristics: These are used as input data for simulating field conditions in the model and should be determined prior to the start of the project. The data may be obtained from either (1) published soil maps, provided they are reliable and include uncertainty estimates, or (2) direct field measurements, following the sampling procedures described in the relevant manuals. Sample preservation and analysis must follow standard or scientifically validated methods to ensure accuracy and reliability.
- Climatic data (e.g. precipitation and air temperature): These data should be continuously recorded or reported. They may be obtained through direct measurements at the project field, referenced from the nearest meteorological station, or estimated using data from multiple nearby stations.

Assessment method 2: Direct measurement

GHG emissions obtained from field measurements in representative fields of the project using the closed chamber method throughout the cropping season of rice should be collected for each sample unit. The GHG emission factor should be calculated as the average of measurement replicates. Alternatively, other scientifically appropriate measurement methods may also be used.

Assessment method 3: Using defaults

The details are presented as outlined above.

To assess the GHG emissions associated with enhanced good practices in paddy rice field under the baseline scenario, it is necessary to estimate the emissions at a level lower than those generated under BAU condition. This can be represented by the following equations:

$$\mathrm{BE}_y = \sum_{s=1}^{m} \mathrm{BE}_s$$

$$\mathrm{BE}_s = \sum_{i=0}^{n} \left((CH_{4\,SOIL,BL,s,i} \times CF) + CO_{2\,LIME,BL,s,i} + CO_{2\,UREA,BL,s,i} + N_2O_{SOIL,BL,s,i} \right)$$

Where:

BE_y	=	Baseline emissions in year *y* (tCO_2eq)
BE_s	=	Baseline emissions in season *s* (tCO_2eq)
$CH_{4\,SOIL,BL,s,i}$	=	Baseline methane emissions from soil carbon pools in season *s* of sample unit i (tCO_2eq)
CF	=	Conservativeness factor for historical emission adjusted downwards (below BAU condition)
$CO_{2\,LIME,BL,s,i}$	=	Baseline carbon dioxide emissions from liming in season *s* of sample unit i (tCO_2eq)
$CO_{2\,UREA,BL,s,i}$	=	Baseline carbon dioxide emissions from urea fertilization in season *s* of sample unit i (tCO_2eq)
$N_2O_{SOIL,BL,s,i}$	=	Baseline nitrous oxide emissions from nitrogen fertilizer application to soil in season *s* of sample unit i (tCO_2eq)
i	=	Sample unit i as described in Table 1 (*n* = total number of sample units)
s	=	Cropping season (*s* = cropping seasons in a year considered in the project activity)

5.1.1 Methane emissions from paddy fields

Methane emissions result from the anaerobic decomposition of organic matter by soil methanogen in the rice fields. Where methane emissions from adjusted water management practices in rice fields are included in the project boundary, the quantitative assessment is conducted by the following equations.

Assessment method 1: Modelling

$$CH_{4SOIL,BL,s,i} = GWP_{CH4} \times fCH_{4SOIL,BL,s,i}$$

Where:

$CH_{4SOIL,BL,s,i}$	=	Baseline methane emissions from soil carbon pools in season *s* of sample unit i (tCO_2eq)
$fCH_{4SOIL,BSL,s,i}$	=	Baseline methane emissions from soil carbon pools modeled in season s of sample unit i (tCH_4)
GWP_{CH4}	=	Global warming potential of methane (tCO_2eq/tCH_4)

Assessment Method 2: Direct measurement

Methane emissions from rice cultivation are assessed based on direct measurements obtained from reference fields of the project, using the following equation.

$$CH_{4SOIL,BL,s,i} = \sum_{i=1}^{n} EF_{CH4BL,s,i} \times A_{s,i} \times 10^{-3} \times GWP_{CH4}$$

Where:

$CH_{4SOIL,BL,s,i}$	=	Baseline methane emissions from soil carbon pools in season *s* of sample unit i (tCO_2eq)
$EF_{CH4BL,s,i}$	=	Baseline methane emission factor from rice cultivation in season *s* of sample unit i ($kgCH_4$/rai/season) The emission factor is obtained from the direct measurements conducted in reference fields of the project using the closed chamber method throughout the entire cropping season. Each sampling unit, categorized by cultivation pattern (Table 1), includes a minimum of three replicates. The methane emission factor is the average of the measured replicates (as detailed in Appendix 2).
GWP_{CH4}	=	Global warming potential of methane (tCO_2eq/tCH_4)
$A_{s,i}$	=	Harvested area of sampling unit i in season *s* (rai)
i	=	Sample unit i covering the entire rice cultivation area of the project (*n* = total number of sample units)

s = Cropping season (S = cropping seasons in a year considered in the project activity)

Assessment method 3: Using defaults

Methane emissions from rice cultivation are estimated using the following equation.

$$CH_{4_{SOIL,BL,s,i}} = \sum_{i=1}^{n} EF_{CH4BL,s,i} \times A_{s,i} \times L_s \times 10^{-3} \times GWP_{CH4}$$

Where:

$CH_{4_{SOIL,BL,s,i}}$ = Baseline methane emissions from soil carbon pools in season s of sample unit i (tCO_2eq)

$EF_{CH4BL,s,i}$ = Baseline methane emission factor from rice cultivation in season s of sample unit i ($kgCH_4$/rai/day)

$A_{s,i}$ = Harvested area of sampling unit i in season s (rai)

L_s = Cultivation period of rice in season s (day)

i = Sample unit i covering the entire rice cultivation area of the project (n = total number of sample units)

s = Cropping season (S = cropping seasons in a year considered in the project activity)

GWP_{CH4} = Global warming potential of methane (tCO_2eq/tCH_4)

When using Tier 1 default emission factors from the IPCC Guidelines, the following equation is applied.

$$EF_{CH4BL,s,i} = EF_{BL,c} \times SF_{BL,w} \times SF_{BL,p} \times SF_{BL,o}$$

$$SF_{BL,o} = \left(1 + \sum_{i} ROA_{BL,s,i,om} \times 0.00625 \times CFOA_{om}\right)^{0.59}$$

Where:

$EF_{CH4BL,s,i}$ = Baseline methane emission factor from rice cultivation in season s of sample unit i ($kgCH_4$/rai/day)

$EF_{BL,c}$ = Emission factor for continuously flooded fields without organic amendments ($kgCH_4$/rai/day)

$SF_{BL,w}$ = Baseline scaling factor to account for the differences in water regime during the cultivation period

$SF_{BL,p}$	=	Baseline scaling factor to account for the differences in water regime in the pre-season before the cultivation period
$SF_{BL,o}$	=	Baseline scaling factor to account for the differences in type and amount of organic amendment applied
$ROA_{BL,s,i,om}$	=	Application rate of organic amendment *om* applied in baseline emission in season *s* of sampling unit i (kg/rai for dry weight for straw and fresh weight for others)
$CFOA_{om}$	=	Conversion factor for organic amendment *om* (in terms of its relative effect with respect to straw applied shortly before cultivation)
0.00625	=	Unit conversion (t/ha)
om	=	Type of organic amendment

5.1.2 Carbon dioxide emissions from liming

Where carbon dioxide emissions from the application of lime materials, such as calcite, calcium carbonate, or calcium magnesium carbonate, are included in the project boundary, the quantitative assessment is conducted under Assessment method 3 by using defaults, as the following equation.

Assessment method 3: Using defaults

$$CO_{2\,LIME,BL,s,i} = \sum\left[\left((M_{Limestone,BL,s,i} \times A_{s,i}) \times EF_{Limestone}\right) + \left((M_{Dolomite,BL,s,i} \times A_{s,i}) \times EF_{Dolomite}\right)\right] \times \frac{44}{12}$$

Where:

$CO_{2\,LIME,BL,s,i}$	=	Baseline carbon dioxide emissions from lime application in season *s* of sample unit i (tCO_2)
$M_{Limestone,BL,s,i}$	=	Amount of limestone in baseline emission in season *s* of sample unit i (t limestone/rai)
$EF_{Limestone}$	=	Emission factor for limestone application (tC/t limestone)
$M_{Dolomite,BL,s,i}$	=	Amount of dolomite in baseline emission in season *s* of sample unit i (t dolomites/rai)
$EF_{Dolomite}$	=	Emission factor for dolomite application (tC/t dolomite)
$A_{s,i}$	=	Harvested area of sampling unit i in season *s* (rai)
$\frac{44}{12}$	=	Conversion of CO_2–C to CO_2

5.1.3 Carbon dioxide emissions from urea fertilization

Conversion of urea by urease enzymes results in the release of carbon dioxide from the urea. In addition, the ammonia derived from urea can undergo transformation, leading to the emission of nitrous oxide, addressed in the following section. Where nitrous oxide emissions from urea fertilization are included in the project boundary, the quantitative assessment is conducted under Assessment method 3 by using defaults, as the following equation.

Assessment method 3: Using defaults

$$CO_{2_{UREA,BL,s,i}} = \sum\left((M_{Urea,BL,s,i} \times A_{s,i}) \times EF_{Urea}\right) \times \frac{44}{12}$$

Where:

$CO_{2_{UREA,BL,s,i}}$	=	Baseline carbon dioxide emissions from urea fertilization in season s of sample unit i (tCO_2)
$M_{Urea,BL,s,i}$	=	Amount of urea fertilization in baseline emission in season s of sample unit i (t urea/rai)
EF_{Urea}	=	Emission factor for urea fertilization (tC/t urea)
$A_{s,i}$	=	Harvested area of sampling unit i in season s (rai)
$\frac{44}{12}$	=	Conversion of CO_2–C to CO_2

5.1.4 Nitrous oxide emissions from nitrogen fertilizers

Nitrogen fertilizers applied to agricultural land, including chemical fertilizers, organic fertilizers, animal manure, and crop residues, are subject to microbial transformation in the soil through nitrification and denitrification processes. During these processes, direct emissions of nitrous oxide are released into the atmosphere. In addition to direct emissions, indirect emissions also occur due to nitrogen losses through volatilization of ammonia and nitrogen oxides, as well as leaching and surface runoff, which subsequently lead to nitrous oxide emissions. Where nitrous oxide emissions from nitrogen fertilizer application are included in the project boundary, the quantitative assessment is conducted by the following equations.

Assessment method 1: Modelling

$$N_2O_{SOIL,BL,s,i} = GWP_{N2O} \times fN_2O_{SOIL,BL,s,i}$$

Where:

$N_2O_{SOIL,BL,s,i}$	=	Baseline nitrous oxide emissions from nitrogen fertilizer application to soil in season s of sample unit i (tCO_2eq)
$fN_2O_{SOIL,BL,s,i}$	=	Baseline nitrous oxide emissions from nitrogen fertilizer application to soil modeled in season s of sample unit i (tN_2O)
GWP_{N2O}	=	Global warming potential of nitrous oxide (tCO_2eq/tN_2O)

Assessment method 2: Direct measurement

Nitrous oxide emissions from nitrogen fertilizer application to soil are assessed based on direct measurements obtained from reference fields of the project, using the following equation.

$$N_2O_{SOIL,BL,s,i} = \sum_{i=1}^{n} EF_{N2OBL,s,i} \times A_{s,i} \times 10^{-3} \times GWP_{N2O}$$

Where:

$N_2O_{SOIL,BL,s,i}$	=	Baseline nitrous oxide emissions from nitrogen fertilizer application to soil in season s of sample unit i (tCO_2eq)
$EF_{N2OBL,s,i}$	=	Baseline nitrous oxide emission factor from nitrogen fertilizer application to the soil in season s of sample unit i (kgN_2O/rai/season) The emission factor is obtained from the direct measurements conducted in reference fields of the project using the closed chamber method throughout the entire cropping season. Each sampling unit, categorized by cultivation pattern (Table 1), includes a minimum of three replicates. The nitrous oxide emission factor is the average of the measured replicates (as detailed in Appendix 2).
GWP_{N2O}	=	Global warming potential of nitrous oxide (tCO_2eq/tN_2O)
$A_{s,i}$	=	Harvested area of sampling unit i in season s (rai)
i	=	Sample unit i covering the entire rice cultivation area of the project (n = total number of sample units)
s	=	Cropping season (S = cropping seasons in a year considered in the project activity)

Assessment method 3: Using defaults

Nitrous oxide emissions from nitrogen fertilizer application to soil are estimated using the following equation with the IPCC defaults.

$$N_2O_{SOIL,BL,s,i} = N_2O_{Direct,BL,s,i} + N_2O_{Indirect,BL,s,i}$$

(1) Direct nitrous oxide emissions from soil

$$N_2O_{Direct,BL,i,t} = (F_{SN,BL,s,i} + F_{ON,BL,s,i}) \times EF_{N2ODirect} \times \frac{44}{28} \times GWP_{N2O}$$

$$F_{SN,BL,s,i} = \sum \left(M_{SN,BL,s,i,j} \times A_{s,i}\right)$$

$$F_{ON,BL,s,i} = \sum \left(M_{ON,BL,s,i,k} \times A_{s,i}\right)$$

(2) Indirect nitrous oxide emissions from soil

$$N_2O_{Indirect,BL,s,i} = N_2O_{ATD,BL,s,i} + N_2O_{L,BL,s,i}$$

$$N_2O_{ATD,BL,s,i} = \left((F_{SN,BL,s,i} \times Frac_{GASF}) + (F_{ON,BL,s,i} \times Frac_{GASM})\right) \times EF_{ATD} \times \frac{44}{28} \times GWP_{N2O}$$

$$N_2O_{L,BL,s,i} = \left(F_{SN,BL,s,i} + F_{ON,BL,s,i}\right) \times Frac_{LEACH} \times EF_{LEACH} \times \frac{44}{28} \times GWP_{N2O}$$

Where:

$N_2O_{SOIL,BL,s,i}$	=	Baseline nitrous oxide emissions from nitrogen fertilizer application to soil in season s of sample unit i (tCO_2eq)
$N_2O_{Direct,BL,s,i}$	=	Baseline direct nitrous oxide emissions from nitrogen fertilizer application to soil in season s of sample unit i (tCO_2eq)
$N_2O_{Indirect,BL,s,i}$	=	Baseline indirect nitrous oxide emissions from nitrogen fertilizer application to soil in season s of sample unit i (tCO_2eq)
$N_2O_{ATD,BL,s,i}$	=	Baseline indirect nitrous oxide emissions from atmospheric deposition of N volatilized, due to nitrogen fertilizer application to soil, in season s of sample unit i (tCO_2eq)
$N_2O_{L,BL,s,i}$	=	Baseline indirect nitrous oxide emissions from leaching and runoff, due to nitrogen fertilizer application to soil, in season s of sample unit i (tCO_2eq)
$F_{SN,BL,s,i}$	=	Amount of synthetic fertilizer nitrogen applied to soils in baseline emission in season s of sample unit i (tN)
$F_{ON,BL,s,i}$	=	Amount of organic nitrogen addition applied to soils in baseline emission in season s of sample unit i (tN)

$EF_{N2ODirect}$	=	Direct nitrous oxide emissions from nitrogen fertilizer application to soil (tN_2O-N/tN)
EF_{ATD}	=	Emission factor for nitrous oxide emissions from atmospheric deposition of nitrogen on soils and water surfaces (tN_2O-N/t NH_3–N + NO_x–N volatilized)
EF_{LEACH}	=	Emission factor for nitrous oxide emissions from nitrogen leaching and runoff (tN_2O-N/tN leached and runoff)
$Frac_{GASF}$	=	Fraction of synthetic fertilizer nitrogen that volatilizes as NH_3 and NO_X (tN NH_3–N + NO_x–N volatized/tN applied)
$Frac_{GASM}$	=	Fraction of organic nitrogen additions that volatilizes as NH_3 and NO_X (tN NH_3–N + NO_x–N volatilized/tN applied)
$Frac_{LEACH}$	=	Fraction of all nitrogen added to/mineralized in soils in regions where leaching/runoff occurs that is lost through leaching and runoff (tN leached and runoff/tN additions)
$M_{SN,BL,s,i,j}$	=	Amount of synthetic fertilizer nitrogen *j* in baseline emission in season *s* of sample unit i (tN/rai)
$M_{ON,BL,s,i,k}$	=	Amount of organic nitrogen *k* in baseline emission in season *s* of sample unit i (tN/rai)
$A_{s,i}$	=	Harvested area of sampling unit i in season *s* (rai)
$\frac{44}{28}$	=	Conversion of N_2O–N to N_2O
GWP_{N2O}	=	Global warming potential of nitrous oxide (tCO_2eq/tN_2O)

5.2 Project emissions

The quantitative assessment of project GHG emissions for enhanced good practices in paddy rice fields can be represented by the following equations:

$$\mathrm{PE}_y = \sum_{s=1}^{m} \mathrm{PE}_s$$

$$PE_s = \sum_{i=0}^{n} \left(CH_{4_{SOIL,PJ,s,i}} + CO_{2_{LIME,PJ,s,i}} + CO_{2_{UREA,PJ,s,i}} + N_2O_{SOIL,PJ,s,i} + CO_{2_{FUEL,PJ,s,i}} + Non - CO_{2_{BURNing,PJ,s,i}} \right)$$

Where:

PE_y	=	Project emissions in year *y* (tCO_2eq)
PE_s	=	Project emissions in season *s* (tCO_2eq)
$CH_{4_{SOIL,PJ,s,i}}$	=	Project methane emissions from soil carbon pools in season *s* of sample unit i (tCO_2eq)
$CO_{2_{LIME,PJ,s,i}}$	=	Project carbon dioxide emissions from liming in season *s* of sample unit i (tCO_2eq)
$CO_{2_{UREA,PJ,s,i}}$	=	Project carbon dioxide emissions from urea fertilization in season *s* of sample unit i (tCO_2eq)
$N_2O_{SOIL,PJ,s,i}$	=	Project nitrous oxide emissions from nitrogen fertilizer application to soil in season *s* of sample unit i (tCO_2eq)
$CO_{2_{FUEL,PJ,s,i}}$	=	Project carbon dioxide emissions from fossil fuel combustion in season *s* of sample unit i (tCO_2eq)
$Non - CO_{2_{BURNing,PJ,s,i}}$	=	Project GHG emissions from biomass burning in season *s* of sample unit *i* (tCO_2eq)
i	=	Sample unit *i* as described in Table 1 (*n* = total number of sample units)
s	=	Cropping season (*s* = cropping seasons in a year considered in the project activity)

The project participant must adopt a consistent methodology for assessing GHG emissions for both the baseline and project emissions.

5.2.1 Methane emissions from fields

The quantitative GHG assessment of project emissions shall follow the same methodologies and equations as those used in the baseline scenario, with the adjustment of notation from "BL" (Baseline) to "PJ" (Project).

5.2.2 Carbon dioxide emissions from liming

The quantitative GHG assessment of project emissions shall follow the same methodologies and equations as those used in the baseline scenario, with the adjustment of notation from "BL" (Baseline) to "PJ" (Project).

5.2.3 Carbon dioxide emissions from urea fertilization

The quantitative GHG assessment of project emissions shall follow the same methodologies and equations as those used in the baseline scenario, with the adjustment of notation from "BL" (Baseline) to "PJ" (Project).

5.2.4 Nitrous oxide emissions from nitrogen fertilizers

The quantitative GHG assessment of project emissions shall follow the same methodologies and equations as those used in the baseline scenario, with the adjustment of notation from "BL" (Baseline) to "PJ" (Project).

5.2.5 Carbon dioxide emissions from fossil fuel combustion

Where project emissions involve the use of machinery or equipment beyond existing management practices, such as laser land leveling for field preparation or the use of water pumps to irrigate or drain rice fields, an assessment of carbon dioxide emissions from fossil fuel combustion must be conducted. This includes emissions from both direct fossil fuel use and electricity consumption (e.g., electric tractors). Where the total GHG emissions resulting from these activities exceed 5% of the total emission reductions achieved by the project, they must be accounted for accordingly.

The quantitative assessment for carbon dioxide emissions from fossil fuel combustion is conducted under Assessment method 3 by using defaults, as the following equation.

Assessment method 3: Using defaults

$$CO_{2\,FUEL,PJ,s,i} = \sum\left((FC_{PJ,s,i,a} \times NCV_a \times 10^{-6} \times EF_{CO2,a}) \times A_{s,i}\right) \times 10^{-3} + \sum(EC_{PJ,s,i} \times EF_{Elec,s} \times (1 + TDL_s) \times A_{s,i})$$

โดยที่:

$CO_{2\,FUEL,PJ,s,i}$	=	Project carbon dioxide emissions from fossil fuel combustion in season s of sample unit i (tCO_2eq)
$FC_{PJ,s,i,a}$	=	Quantity of fuel a in project emission in season s of sample unit i (*unit/rai*)

$A_{s,i}$	=	Harvested area of sampling unit i in season s (rai)
NCV_a	=	Net calorific value (NCV) of fuel a (MJ/unit)
$EF_{CO2,a}$	=	Emission factor for combustion of fossil fuel a (kgCO_2/TJ)
a	=	Fossil fuel type
$EC_{PJ,s,i}$	=	Electricity consumption in project emission in season s of sampling unit i (MWh/rai)
$EF_{Elec,s}$	=	Emission factor for electricity generation/consumption in season s (tCO_2/MWh)
TDL_s	=	Proportion of power losses in the electrical network for electricity supply to end-use locations in season s

5.2.6 Non-CO_2 emissions from biomass burning

Where the project involves the field burning of rice straw and stubble within the project area, and the resulting GHG emissions exceed 5% of the total emission reductions, the project is required to assess the emissions from biomass burning using Assessment Method 3 with defaults, as the following equation.

Assessment method 3: Using defaults

$$Non-CO_{2\,BURNing,PJ,s,i} = \frac{\sum MB_{PJ,s,i} \times C_f \times A_{burn,s,i} \times [(EF_{CH4} \times GWP_{CH4}) + (EF_{N2O} \times GWP_{N2O})]}{10^6}$$

Where:

$Non-CO_{2\,BURNing,PJ,s,i}$	=	Project GHG emissions from biomass burning in season s of sample unit i (tCO_2eq)
$MB_{PJ,s,i}$	=	Mass of fuel available for combustion, including rice stubble and straw, for project emission in season s of sample unit i (kg/rai)
C_f		Combustion factor for rice stubble and straw (fraction on biomass being burnt in the field)
$A_{burn,s,i}$	=	Area burnt in season s of sample unit i (rai)
EF_{CH4}	=	Methane emission factor for biomass burning (gCH_4/kg dry matter of biomass burnt)

EF_{N2O}		Nitrous oxide emission factor for biomass burning (gN_2O/kg dry matter of biomass burnt)
GWP_{CH4}	=	Global warming potential of methane (tCO_2eq/tCH_4)
GWP_{N2O}	=	Global warming potential of nitrous oxide (tCO_2eq/tN_2O)
10^6	=	Unit conversion (g/t)

6. Leakage emissions

Any GHG emissions resulting from project activities that occur beyond the established project boundary are considered negligible and, as such, are excluded from consideration under this methodology.

7. Net GHG emission reductions

$$ER_y = (BE_y - PE_y - LE_y) \times (1 - U_d)$$

Where:

ER_y	=	Emission reductions in year *y* (tCO_2eq)
BE_y	=	Baseline emissions in year *y* (tCO_2eq)
PE_y	=	Project emissions in year *y* (tCO_2eq)
LE_y	=	Leakage emissions outside project boundaries in year *y* (tCO_2eq)
U_d	=	Uncertainty deduction factor (Where the project participant selects Assessment method 3, the uncertainty deduction is set at 15%)

8. Uncertainty

The project participant must assess the uncertainty associated with the estimated GHG emission reductions resulting from project activities. Depending on the selected assessment approach, the project participant is required to choose an appropriate uncertainty assessment method that aligns with internationally recognized principles. The selected method must be clearly referenced and must adhere to the principle of conservativeness. In cases where the uncertainty of the project exceeds the initial specified value, the resulting value must be deducted from the net emission reductions of project activities.

Assessment method 1 and 2: When the uncertainty in the mean value of a parameter assessment exceeds 20% at a 90% confidence level, the mean value shall be adjusted downward based on the percentage of uncertainty, as follows:

<table>
<tr><th>Uncertainty (U)</th><th>Uncertain Deduction Factor (U_d)</th><th>Applicability</th></tr>
<tr><td>20<U≤30</td><td>50%</td><td rowspan="3"><u>Example</u>
Mean value = 60 ± 15 tCO_2eq
Calculate uncertainty (U) = 15/60 x 100 = 25%
Deduction factor (U_d) = 25% x 15 = 3.75 tCO_2eq
The discount calculation is based on principle of conservativeness as follows:
<u>Baseline</u> = 60 - 3.75 = 56.25 tCO_2eq
<u>Project implementation</u> = 60 + 3.75 = 63.75 tCO_2eq</td></tr>
<tr><td>30<U≤40</td><td>75%</td></tr>
<tr><td>U>40</td><td>100%</td></tr>
</table>

Remark: tCO_2eq = ton carbon dioxide equivalent

Assessment method 3: the U_d is set at 15%.

9. Monitoring Procedure

9.1 Monitoring Plan

The project monitoring plan involves the preparation and collection of data required to quantify reductions in GHG emissions from project activities. It must ensure that farmers implement good practices in rice cultivation and record data as specified in the project design document.

9.2 Monitoring of project implementation

Monitoring data for project implementation shall be specified in the Project Design Document (PDD). The parameters to be monitored, including measurement methods and monitoring frequency, must comply with the requirements set forth by TGO.

10. Relevant Parameters

10.1 Parameter not required monitoring

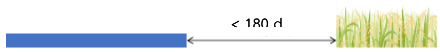
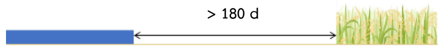
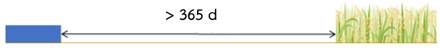
Parameters	CF
Unit	-
Description	Conservativeness factor for historical emission adjusted downwards (below BAU condition) A value of **0.89** is applied.
Source of data	UNFCCC/FCCC/SBSTA/2015/L.13 Table 1: Conservativeness factors for adjustments to emission estimates in the base year or recovery estimates in the commitment period (Rice Cultivation)
Remark	-

Parameters	$EF_{BL,c}$
Unit	$kgCH_4$/rai/day
Description	Emission factor for continuously flooded fields without organic amendments In cases where the IPCC default is applied, a value of **0.1952** $kgCH_4$/rai/d
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 5 Table 5.11 (Southeast Asia = **1.22** $kgCH_4$/ha/day)
Remark	-

Parameters	$SF_{BL,w}$ or $SF_{PJ,w}$
Unit	-
Description	Baseline or project scaling factor to account for the differences in water regime during the cultivation period In case where the IPCC default is applied: Continuously flooded: **1.00** Intermittent flooded (single drainage): **0.71** Intermittent flooded (multiple drainage and AWD): **0.55**
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 5 Table 5.12
Remark	**Continuously flooded:** Fields have standing water throughout the rice growing season and may only dry out about 1-2 weeks for harvest (end-season drainage). **Intermittently flooding (single drainage):** Fields have a single aeration by water drainage or field drying during the cropping season. This

<table>
<tr><td></td><td>practice involves either allowing the field to dry to soil surface or below, without adverse effects on rice growth or yield. Fields may only dry for harvest (except for end-season drainage).
Intermittently flooding (multiple drainage): Fields have more than one aeration period by water drainage or field drying during the cropping season and may only dry for harvest (except for end-season drainage). AWD method is also included. This practice requires the field to dry to soil surface or below, without adverse effects on rice growth or yield. A dry condition is defined as a water level that falls 10–15 cm below the soil surface, or as otherwise recommended by relevant scientific guidance.
In cases where the project is unable to maintain water drainage to a depth of 10–15 cm below the soil surface, the SF_w corresponding to the “intermittent flooding with single drainage or aeration” shall be applied, in accordance with principles of conservativeness.</td></tr>
</table>

<table>
<tr><td>Parameters</td><td>$SF_{BL,p}$ or $SF_{PJ,p}$</td></tr>
<tr><td>Unit</td><td>-</td></tr>
<tr><td>Description</td><td>Baseline and project scaling factor to account for the differences in water regime in the pre-season before the cultivation period
In case where the IPCC default is applied:
<table>
<tr><td>Flooded pre-season >30 days</td><td>2.41</td></tr>
<tr><td>Non-flooded pre-season <180 days or short flooding <30 days</td><td>1.00</td></tr>
<tr><td>Non-flooded pre-season >180 days</td><td>0.89</td></tr>
<tr><td>Non-flooded pre-season >365 days or upland crop - paddy rotation (or fallow without flooding in previous year)</td><td>0.59</td></tr>
</table></td></tr>
<tr><td>Source of data</td><td>IPCC Guidelines 2019, Volume 4, Chapter 5 Table 5.13</td></tr>
<tr><td>Remark</td><td>
<table>
<tr><td>Flooded pre-season >30 days</td><td>
</td></tr>
<tr><td>Short flooding pre-season <30 days</td><td>
</td></tr>
</table></td></tr>
</table>

	Non-flooded pre-season <180 days	
	Non-flooded pre-season >180 days	
	Non-flooded pre-season >365 days	

Parameters	$ROA_{BL,s,i,om}$
Unit	kg/rai for dry weight for straw and fresh weight for others
Description	Application rate of organic amendment *om* applied in baseline emission in season *s* of sampling unit i
Source of data	Historical cultivation data for a period of no less than three years, or relevant and site-appropriate study reports, must be obtained from credible official sources. These may include government agencies, expert interviews, farmer interviews, or field measurements, with the option of using sampling methods where applicable.
Remark	-

Parameters	$CFOA_{om}$
Unit	-
Description	Conversion factor for organic amendment om (in terms of its relative effect with respect to straw applied shortly before cultivation) In case where the IPCC default is applied: Straw incorporated shortly (<30 days) before cultivation: **1.00** Straw incorporated long (>30 days) before cultivation: **0.19** Farmyard manure: **0.21** Compost: **0.17** Green manure: **0.45**
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 5 Table 5.14
Remark	-

Parameters	$M_{Limestone,BL,s,i}$

Unit	t limestone/rai
Description	Amount of limestone in baseline emission in season s of sample unit i
Source of data	Historical cultivation records covering a period of no less than three years, or published documents that are appropriate for the project area. The data should be in-line or be consistent with relevant documents from credible and official sources, interviews with farmers, expert consultations, purchase records, farmers' logbooks, or direct measurements, which may be conducted using sampling methods.
Remark	-

Parameters	$M_{Dolomite,BL,s,i}$
Unit	t dolomites/rai
Description	Amount of dolomite in baseline emission in season s of sample unit i
Source of data	Historical cultivation records covering a period of no less than three years, or published documents that are appropriate for the project area. The data should be in-line or be consistent with relevant documents from credible and official sources, interviews with farmers, expert consultations, purchase records, farmers' logbooks, or direct measurements, which may be conducted using sampling methods.
Remark	-

Parameters	$EF_{Limestone}$
Unit	tC/t limestone
Description	Emission factor for limestone application In cases where the IPCC default is applied, a value of 0.12 is assigned.
Source of data	IPCC Guidelines 2006, Volume 4, Chapter 11.3
Remark	-

Parameters	$EF_{Dolomite}$
Unit	tC/t dolomite
Description	Emission factor for dolomite application In cases where the IPCC default is applied, a value of 0.13 is assigned.
Source of data	IPCC Guidelines 2006, Volume 4, Chapter 11.3
Remark	-

Parameters	$M_{Urea,BL,s,i}$
Unit	t urea/rai

Description	Amount of urea fertilization in baseline emission in season s of sample unit i
Source of data	Historical cultivation records covering a period of no less than three years, or published documents that are appropriate for the project area. The data should be in-line or be consistent with relevant documents from credible and official sources, interviews with farmers, expert consultations, purchase records, farmers' logbooks, or direct measurements, which may be conducted using sampling methods.
Remark	-

Parameters	EF_{Urea}
Unit	tC/t urea
Description	Emission factor for urea fertilization In cases where the IPCC default is applied, a value of 0.20 is assigned.
Source of data	IPCC Guidelines 2006, Volume 4, Chapter 11.4
Remark	-

Parameters	$M_{SN,BL,s,i,j}$
Unit	tN/rai
Description	Amount of synthetic fertilizer nitrogen j in baseline emission in season s of sample unit i (tN/rai)
Source of data	Historical cultivation records covering a period of no less than three years, or published documents that are appropriate for the project area. The data should be in-line or be consistent with relevant documents from credible and official sources, interviews with farmers, expert consultations, purchase records, farmers' logbooks, or direct measurements, which may be conducted using sampling methods.
Remark	-

Parameters	$M_{ON,BL,s,i,k}$
Unit	tN/rai
Description	Amount of organic nitrogen k in baseline emission in season s of sample unit i
Source of data	Historical cultivation records covering a period of no less than three years, or published documents that are appropriate for the project area. The data should be in-line or be consistent with relevant documents from credible and official sources, interviews with farmers,

	expert consultations, purchase records, farmers' logbooks, or direct measurements, which may be conducted using sampling methods.
Remark	-

Parameters	$EF_{N2O,Direct}$
Unit	$tN_2O\text{-}N/tN$
Description	Direct nitrous oxide emissions from nitrogen fertilizer application to soil (synthetic and organic fertilizers, organic amendments and crop residues) In cases where the IPCC default is applied: Continuous flooding: **0.003** Single and multiple drainage: **0.005**
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 11, Table 11.1
Remark	-

Parameters	$Frac_{GASF}$
Unit	t NH_3-N + NO_X-N volatized/tN applied
Description	Fraction of synthetic fertilizer nitrogen that volatilizes as NH_3 and NO_X In cases where the IPCC default is applied, a value of **0.11** is assigned.
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 11, Table 11.3
Remark	-

Parameters	$Frac_{GASM}$
Unit	t NH_3-N + NO_X-N/tN
Description	Fraction of organic nitrogen additions that volatilizes as NH_3 and NO_X In cases where the IPCC default is applied, a value of **0.21** is assigned.
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 11, Table 11.3
Remark	-

Parameters	EF_{ATD}
Unit	tN_2O-N/t NH_3–N + NO_x–N volatilized
Description	Emission factor for nitrous oxide emissions from atmospheric deposition of nitrogen on soils and water surfaces In cases where the IPCC default is applied, a value of **0.010** is assigned.
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 11, Table 11.3
Remark	-

Parameters	$Frac_{LEACH}$

Unit	tN leached and runoff/tN additions
Description	Fraction of all nitrogen added to/mineralized in soils in regions where leaching/runoff occurs that is lost through leaching and runoff In cases where the IPCC default is applied, a value of **0.24** is assigned.
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 11, Table 11.3
Remark	-

Parameters	EF_{LEACH}
Unit	tN_2O-N/tN leached and runoff
Description	Emission factor for nitrous oxide emissions from nitrogen leaching and runoff In cases where the IPCC default is applied, a value of **0.011** is assigned.
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 11, Table 11.3
Remark	-

Parameters	NCV_a
Unit	MJ/unit
Description	Net calorific value (NCV) of fuel a
Source of data	Option 1 The net calorific value of fossil fuels indicated on the invoice from the fuel supplier. Option 2 From monitoring Option 3 Thailand Energy Statistics Report, Department of Alternative Energy Development and Efficiency, Ministry of Energy
Remark	-

Parameters	$EF_{CO_2,a}$
Unit	$kgCO_2/TJ$
Description	Emission factor for combustion of fossil fuel a
Source of data	IPCC Guidelines 2006, Volume 2, Chapter 1, Table 1.4
Remark	-

Parameters	EF_{CH4}
Unit	gCH_4/kg dry matter of biomass burnt
Description	Methane emission factor for biomass burning In cases where the IPCC default is applied, a value of **2.7** is assigned.
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 2, Table 2.5
Remark	-

Parameters	EF_{N2O}
Unit	gN_2O/kg dry matter of biomass burnt
Description	Nitrous oxide emission factor for biomass burning In cases where the IPCC default is applied, a value of **0.07** is assigned.
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 2, Table 2.5
Remark	-

Parameters	C_f
Unit	fraction on biomass being burnt in the field
Description	Combustion factor for rice stubble and straw In cases where the IPCC default is applied, a value of **0.8** is assigned.
Source of data	IPCC Guidelines 2019, Volume 4, Chapter 2, Table 2.6
Remark	-

Parameters	$\boldsymbol{TDL_s}$
Unit	-
Description	Proportion of power losses in the electrical network for electricity supply to end-use locations in season *s* A value of **0.03** (3%) is assigned.
Source of data	-
Remark	-

For other parameters not required monitoring, details appear in relevant calculation tools.

10.2 Parameters monitored

Parameters	GWP_{CH4}
Unit	tCO_2eq/tCH_4
Description	Global warming potential of methane
Source of data	IPCC Assessment Report
Monitoring method	For PDD preparation – Apply the latest GWP_{CH4} announced by TGO For monitoring

	– Apply GWP_{N2O} announced by TGO for assessing amount of GHGs during the crediting period for which the amount of GHG certification is requested.

Parameters	GWP_{N2O}
Unit	tCO_2eq/tN_2O
Description	Global warming potential of nitrous oxide
Source of data	IPCC Assessment Report
Monitoring method	<u>For PDD preparation</u> – Apply the latest GWP_{CH4} announced by TGO <u>For monitoring</u> – Apply GWP_{N2O} announced by TGO for assessing amount of GHGs during the crediting period for which the amount of GHG certification is requested.

Parameters	$A_{s,i}$
Unit	Rai
Description	Harvested area of sampling unit i in season s
Source of data	Georeferenced land area survey report
Monitoring method	- Area exploration - Use satellite imagery or aerial photography
Monitoring frequency	Every cropping season
Remark	In case where an area engages in activities that significantly deviate from those specified by the project, that area shall be excluded from consideration in determining the total project area for that particular season.

Parameters	L_s
Unit	Days
Description	Cultivation period of rice in season s
Source of data	Records
Monitoring method	Recorded by farmers or project participants using appropriate methods
Monitoring frequency	Every cropping season
Remark	-

Parameters	Water regime (on-season)
Unit	-
Description	• Continuously flooded • Intermittent flooded (single drainage) • Intermittent flooded (multiple drainage and AWD): Dry condition is defined as a water level that falls 10–15 cm below the soil surface
Source of data	Records
Monitoring method	Recorded by farmers or project participants using appropriate methods
Monitoring frequency	Entire cropping season
Remark	-

Parameters	Water regime (pre-season)
Unit	-
Description	• Flooded pre-season >30 days • Short flooding (pre-season) <30 days • Non-flooded pre-season <180 days • Non-flooded pre-season >180 days • Non-flooded pre-season >365 days or upland crop - paddy rotation (or fallow without flooding in previous year)
Source of data	Recorded
Monitoring method	Recorded by farmers or project participants using appropriate methods
Monitoring frequency	Entire cropping season
Remark	-

Parameters	$EF_{CH4BL,s,i}$
Unit	$kgCH_4$/rai/season
Description	Baseline methane emission factor from rice cultivation in season s of sample unit i
Source of data	The emission factor is obtained from the direct measurements conducted in reference fields of the project using the closed chamber method throughout the entire cropping season. Each sampling unit,

	categorized by cultivation pattern (Table 1), includes a minimum of three replicates. The methane emission factor is the average of the measured replicates.
Monitoring method	Appendix 2
Monitoring frequency	Appendix 2
Remark	-

Parameters	$EF_{CH4PJ,s,i}$
Unit	$kgCH_4$/rai/season
Description	Project methane emission factor from rice cultivation in season s of sample unit i
Source of data	The emission factor is obtained from the direct measurements conducted in reference fields of the project using the closed chamber method throughout the entire cropping season. Each sampling unit, categorized by cultivation pattern (Table 1), includes a minimum of three replicates. The methane emission factor is the average of the measured replicates.
Monitoring method	Appendix 2
Monitoring frequency	Appendix 2
Remark	-

Parameters	$EF_{N2OBL,s,i}$
Unit	kgN_2O/rai/season
Description	Baseline nitrous oxide emission factor from nitrogen fertilizer application to the soil in season s of sample unit i (kgN_2O/rai/season)
Source of data	The emission factor is obtained from the direct measurements conducted in reference fields of the project using the closed chamber method throughout the entire cropping season. Each sampling unit, categorized by cultivation pattern (Table 1), includes a minimum of three replicates. The nitrous oxide emission factor is the average of the measured replicates.
Monitoring method	Appendix 2

Monitoring frequency	Appendix 2
Remark	-

Parameters	$EF_{N2OPJ,s,i}$
Unit	kgN_2O/rai/season
Description	Project nitrous oxide emission factor from nitrogen fertilizer application to the soil in season s of sample unit i (kgN_2O/rai/season)
Source of data	The emission factor is obtained from the direct measurements conducted in reference fields of the project using the closed chamber method throughout the entire cropping season. Each sampling unit, categorized by cultivation pattern (Table 1), includes a minimum of three replicates. The nitrous oxide emission factor is the average of the measured replicates.
Monitoring method	Appendix 2
Monitoring frequency	Appendix 2
Remark	-

Parameters	$M_{Limestone,PJ,s,i}$
Unit	t limestone/rai
Description	Amount of limestone in project emission in season s of sample unit i
Source of data	Records
Monitoring method	Recorded by farmers or project participants using appropriate methods
Monitoring frequency	Entire cropping season
Remark	-

Parameters	$M_{Dolomite,PJ,s,i}$
Unit	t dolomite/rai
Description	Amount of limestone in project emission in season s of sample unit i
Source of data	Records
Monitoring method	Recorded by farmers or project participants using appropriate methods

Monitoring frequency	Entire cropping season
Remark	-

Parameters	$M_{Urea,PJ,s,i}$
Unit	t urea/rai
Description	Amount of urea in project emission in season s of sample unit i
Source of data	Records
Monitoring method	Recorded by farmers or project participants using appropriate methods
Monitoring frequency	Entire cropping season
Remark	-

Parameters	$M_{SN,PJ,s,i,j}$
Unit	tN/rai
Description	Amount of synthetic fertilizer nitrogen j in project emission in season s of sample unit i
Source of data	Records
Monitoring method	Recorded by farmers or project participants using appropriate methods
Monitoring frequency	Entire cropping season
Remark	-

Parameters	$M_{ON,PJ,s,i,k}$
Unit	tN/rai
Description	Amount of organic nitrogen k in project emission in season s of sample unit i
Source of data	Records
Monitoring method	Recorded by farmers or project participants using appropriate methods
Monitoring frequency	Entire cropping season
Remark	-

Parameters	$FC_{PJ,s,i,a}$

Unit	*unit/rai*
Description	Quantity of fuel a in project emission in season *s* of sample unit i
Source of data	Records
Monitoring method	Option 1: In case where fuel is purchased or disbursed and used entirely at once without storage, fuel usage should be tracked using invoices or disbursement records that indicate the quantity of fuel consumed. Option 2: In case where fuel is stored in containers and used from storage, the mass or volume of fuel consumed should be measured, and fuel usage should be continuously recorded.
Monitoring frequency	Entire cropping season
Remark	-

Parameters	$MB_{PJ,s,i}$
Unit	kg/rai
Description	Mass of fuel available for combustion, including rice stubble and straw, for project emission in season *s* of sample unit i
Source of data	Records
Monitoring method	Option 1: Sampling of above-ground biomass in the area prior to burning shall be conducted using sample plots of 1 x 1 m in size, with a minimum of three replicates per sampling unit. Option 2: fraction of agricultural residue to crop yield shall be determined based on appropriate reference documents relevant to the project area.
Monitoring frequency	Entire cropping season
Remark	-

Parameters	$ROA_{PJ,s,i,om}$
Unit	kg/rai for dry weight for straw and fresh weight for others
Description	Application rate of organic amendment *om* applied in project emission in season s of sampling unit i
Source of data	Records
Monitoring method	Recorded by farmers or project participants using appropriate methods
Monitoring frequency	Entire cropping season

Remark	-

Parameters	$fCH_{4\,SOIL,BSL,i,t}$
Unit	tCH_4
Description	Baseline methane emissions from soil carbon pools modeled in season s of sample unit $\boldsymbol{i}$
Source of data	Measurement report
Monitoring method	A description of the selected assessment methodology, including procedures for sample and data collection, the use of reference or default parameters from credible sources, and the calculation of results using appropriate equations.
Monitoring frequency	Aligned with the monitoring schedule for credit certification
Remark	-

Parameters	$fN_2O_{SOIL,BL,s,i}$
Unit	tN_2O
Description	Baseline nitrous oxide emissions from nitrogen fertilizer application to soil modeled in season s of sample unit $\boldsymbol{i}$
Source of data	Measurement report
Monitoring method	A description of the selected assessment methodology, including procedures for sample and data collection, the use of reference or default parameters from credible sources, and the calculation of results using appropriate equations.
Monitoring frequency	Aligned with the monitoring schedule for credit certification
Remark	-

Parameters	$\boldsymbol{EC_{PJ,s,i}}$
Unit	MWh/rai
Description	Electricity consumption in project emission in season s of sampling unit $\boldsymbol{i}$
Source of data	Measurement report
Monitoring method	Option 1: Measurement by kWh meter Option 2: Calculation based on the rated power provided by the machinery/equipment manufacturer, along with recorded operating hours of the machinery/equipment

Monitoring frequency	Entire cropping season
Remark	-

Parameters	$EF_{Elec,s}$
Unit	tCO_2/MWh
Description	Emission factor for electricity generation/consumption in season *s*
Source of data	Announcement on emission factor from electricity generation/consumption for greenhouse gas mitigation projects and activities by TGO
Monitoring method	<u>For PDD preparation</u> – Apply the latest $EF_{Elec,y}$ announced by TGO <u>For monitoring</u> - Apply the $EF_{Elec,y}$ announced by TGO to assess the amount of GHG emissions during the crediting period for which certification is requested. In cases where no $EF_{Elec,y}$ has been announced for a given year within the crediting period, the most recently $EF_{Elec,y}$ by TGO shall be used as a substitute for that year.

For other parameters required monitoring, details appear in relevant calculation tools.

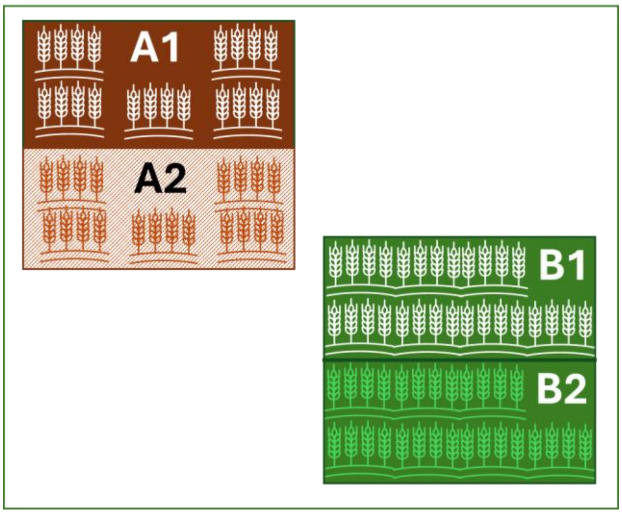
Appendix

Appendix 1: Determining representative or reference fields for rice cultivation

Criteria for determining representative or reference fields

The selection of representative areas for estimating GHG emissions from rice cultivation should consider key factors such as climate conditions, soil characteristics, rice cultivation systems (e.g., wet-season rice within or outside irrigated areas, deepwater rice, or dry-season rice), rice varieties, and agricultural management practices. The process should be carried out as follows:

1. The collection of data on climatic conditions, soil properties, and rice cultivation systems—particularly through integration into Geographic Information Systems (GIS)—facilitates the stratification of sampling areas based on spatial datasets and controlling factors on GHG emissions.
2. In cases where the classification of areas based on environmental factors yields limited group diversity, the sampling process may proceed to the next stage. However, if the classification results in a high degree of heterogeneity, it may be necessary to revise the sampling framework by aggregating similar groups into broader categories to ensure feasibility and representativeness in subsequent sampling efforts.
3. After initial classification based on environmental factors, additional variables influencing GHG emissions should be considered. These include rice variety, pre-planting field preparation, specific agricultural practices—particularly water management practices—the use of chemical and organic fertilizers, and the management of crop residues.
4. In case relevant spatial data are available, geospatial analysis techniques using GIS should be applied to delineate and classify rice cultivation areas according to the specified categories.
5. If data—particularly on farmers' management practices—are insufficient, field surveys or classification of local practices may be required. The collected data can then be used to delineate areas based on rice cultivation practices.
6. Representative rice cultivation areas should be selected based on the criteria outlined above, ensuring a sufficient number of sites or samples to allow for statistical analysis. For example, a minimum of three replicates per group is recommended to enhance the reliability of subsequent assessments.



The example project area shown in the figure above is divided into two rice cultivation areas: Area A and Area B. These areas differ in terms of soil and rice cultivation practices. Area A consists of a single soil series but is further divided into two sub-areas, A1 and A2, based on different rice varieties grown. Area B, on the other hand, is characterized by a soil series distinct from that of Area A and is subdivided into plots B1 and B2 according to differences in rice cultivation practices.

Project participants must present the rationale and results of the delineation of representative agricultural areas within the project. This can be illustrated through diagrams and/or tables detailing the area characteristics, including geographic coordinates referenced using an appropriate system, such as UTM. These representations will support subsequent procedures such as project verification or renewal. Additionally, the explanation must be accompanied by relevant scientific or academic evidence to justify the delineation.

Sample size of representative sampling plots

Determining the appropriate number of sampling plots should be based on statistical method. A commonly used approach involves setting a confidence level of 90% and a precision level of 10%. Alternative approaches may be used if properly justified.

Examples of data sources for determination on representative agricultural areas and sample sizes

- Standard for Sampling and surveys for CDM project activities and programmes of activities.
- FAO (2019). Measuring and modelling soil carbon stocks and stock changes in livestock production systems: Guidelines for assessment (Version 1). Livestock Environmental Assessment and Performance (LEAP) Partnership.

- FAO (2020). A protocol for measurement, monitoring, reporting and verification of soil organic carbon in agricultural landscapes – GSOC-MRV Protocol. Rome, FAO.

Appendix 2: Guidelines for measuring methane emissions from rice fields

- Project participants must ensure that the reference fields of the project are subject to the same conditions as those used for the baseline scenario, as detailed in Table 1. Ideally, the project reference fields should be located in close proximity to the baseline reference fields and should commence the cropping season at approximately the same time. If the reference fields exhibit significant deviations in management practices from those prescribed by the project, they can no longer be considered representative under the principle of conservativeness. Such fields shall be excluded from the calculation of the total project area (A_{sg}) for that season. This requirement ensures that only those rice fields that align with the project's cultivation practices are considered in the calculation of GHG emission reductions.
- The implementation of methane or nitrous oxide measurement in rice fields requires the involvement of experts in this field or at least experienced staff trained by experts.
- Project participants must prepare a comprehensive plan and detailed procedures for sample collection and laboratory analysis to determine the GHG emission factors from rice fields prior to the start of the season. The plan should include key components such as the identification of representative rice fields for the project, covering variations in climate, soil, water management, rice and other crop varieties, fertilizer and organic material applications. It must also include a cropping calendar, a schedule for gas sampling, and procedures for sample analysis.

On the field - technical options for the chamber design are outlined as follows.

Feature	Conditions	
Chamber materials	Option 1: Non-transparent • Commercially available 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	Option 2: Transparent • Manufactured chambers using acrylic glass; • Advantage of transparent chambers: could be placed for longer time spans on the field if equipped with a lid that remains open between measurements and is only closed during measurements;

Feature	Conditions	
	30 min) followed by immediate removal from the field	• Only suitable for short-term exposure (typically 30 min), as prolonged use may affect crop growth
Placement in soil	Option 1: Fixed base • Based 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; • Based should be installed at least 24 hours before the first sampling	Option 2: Without base • Chamber lave to be placed on the soil with open lid to allow escape of eventual ebullition
Auxiliaries of chamber	• Thermometer for measuring the temperature inside the chamber; • Fan (battery operated) inside the chamber for mix the inside air during sampling; • Sampling port with rubber stopper placed in a bore of the chamber or connecting a silicone tube to a three-way valve and a syringe for sample collection	
Basal area	Rounded or rectangular, and has to cover minimum of four rice hills or ca. 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 height or modular design

On the field – air sampling

Feature	Conditions
Replicate chambers per plot	Minimum requirement: Three replicate chambers per plot
Number of air samples per exposure (per chamber and sampling time)	Minimum requirement: Three samples per exposure (per chamber and sampling time)
Exposure time	20-30 min over multiple time intervals (not fewer than three), e.g., 0, 5, 10, and 20 min after the chamber lid is closed
Daytime of measurement	Morning
Measurement interval	Minimum requirement: once per week throughout the cropping season (from the beginning of rice cultivation until before harvest)
Vial or gas sampling bag	Vials or gas sampling bags must be evacuated to create a vacuum before each sampling. The containers must be in proper working condition—capable of effectively collecting gas samples without leakage. Prior to use, the condition of each vial or bag must be inspected, and appropriate gas collection equipment should be used to ensure ease of operation and reliability during sampling.
Sample storage until analysis	• Storage < 24 h: air samples can remain in vial or gas bag • Storage > 24 h: air samples can remain in evacuated vial, store with slight over pressure
Suggestion	1) Gas sampling containers should be glass vials or gas sampling bags. The use of blood collection tubes is not recommended for gas sampling, as they may contain substances related to blood coagulation and could potentially react with nitrous oxide, compromising sample integrity. 2) To collect gas samples, a bridge or platform should be extended into the rice field to prevent disturbance to the soil and rice plants during sampling

Laboratory analysis of gas samples

Feature	Conditions
Method	Gas Chromatograph with flame ionization detector (FID) for methane and electron capture detector (ECD) for nitrous oxide
Injection	Direct injection or with multi-port valve and sample loop
Column	Packed or capillary column
Calibration	With certified standard gas each day of analysis before and after the analyses are done

Calculation of the emission rate of methane and nitrous oxide from rice field

Step 1 Calculation of the mass of methane and nitrous oxide emissions from gas sample analysis is expressed by the following equations:

$$m_t = C_t \times V_{chamber} \times M \times \frac{1\ atm}{R \times T_t \times 1000}$$

$$RE_{ch} = s \times \frac{60\ min}{A_{chamber}}$$

$$RE_{plot} = \frac{\sum RE_{ch}}{N_{ch}}$$

Where:

m_t	Mass of methane or nitrous oxide in chamber at time t (mg)
t	Point of time of sample (e.g., 0, 5, 10, 15, 30 in case of three samples within 30 min) after close the lid
C_t	Methane or nitrous oxide concentration in chamber at time *t* from gas analysis (ppm)
$V_{chamber}$	Chamber volume (l)
M_{CH4}	Molecular weight of methane or nitrous oxide (16.042 or 44.0128 g/mol, respectively)
$1\ atm$	Assume constant pressure at 1 atm, unless pressure measurement is installed

R	Universal gas constant (0.08206 l*atm/K/mol)
T_t	Temperature at time *t* (K)

Step 2 Determine the rate of change in the mass of methane or nitrous oxide over time (or determination of the slope of the line of best fit for the values of over time):

$$s = \frac{\Delta m}{\Delta t}$$

Where:

s	Slope of line of best fit for the values of mass of methane or nitrous oxide over time (mg/min)

Step 3 Calculate the emission rate per hour for one chamber measurement.:

$$RE_{ch} = s \times \frac{60\ min}{A_{chamber}}$$

Where:

RE_{ch}	Emission rate of chamber *ch* (mg/h*m^2)
ch	Index for replicate chamber on a plot
$A_{chamber}$	Chamber area (m^2)

ขั้นที่ 4 Calculate the average emission rate of a chamber measurement per plot:

$$RE_{plot} = \frac{\sum RE_{ch}}{N_{ch}}$$

Where:

RE_{plot}	Average emission rate of a plot (mg/h*m^2)
N_{ch}	Number of replicate chambers per plot

Step 5 Calculate the cumulative emissions during each sampling interval or week over the entire cropping season. The results should be reported in units of mg/m² or kg/rai:

$$E_i = \frac{(Rh_i + Rh_{i+1}) \times 24h \times D_i}{2}$$

Where:

E_i	Cumulative emission during each sampling interval *i* (mg/m^2)
Rh_i	Hourly emission rate at the beginning time interval *i* (mg/m^2/h)
Rh_{i+1}	Hourly emission rate at the end of time interval *i* (mg/m^2/h)
D_i	Days for sampling interval *i* (d)

Note: Gas fluxes on the day of planting and at harvest may be assumed to be zero if no measurements are conducted on those days.

Step 6 Calculate the cumulative emission of the plots throughout the cropping season:

$$E = \sum_{i=1}^{N} E_i \times 0.0016$$

Where:

E	Cumulative emission of methane or nitrous oxide over the season (kg/rai/season)
N	Number of measurement events conducted during cropping season
0.0016	Unit conversion from mg/m^2/season to kg/rai/season

Step 7 Calculate emission factors for each cropping season

$$EF_s = \frac{\sum_{f=1}^{F} E_f}{F}$$

Where:

EF_s	Emission factor in season *s* (kg/rai/season)
E_f	Cumulative emission of plot *f* in season *s* (kg/rai/season)
F	Number of representative rice fields in each season

Alternative: Calculate daily emission factor for each cropping season

$$EF_{s,d} = \frac{\frac{\sum_{f=1}^{F} E_f \, x \, 10^{-2}}{D_f}}{F}$$

Where:

$EF_{s,d}$	Daily emission factor in season s (kg/rai/d)
E_f	Cumulative emission of plot f in season s (kg/rai/season)
D_f	Days for rice cultivation of plot f in season s (d/season)
F	Number of representative fields in each season

Appendix 3: Concepts on model application and uncertainty analysis

A model of GHG emissions from rice cultivation

GHG emissions from rice cultivation areas can be estimated and predicted using various modelling approaches, ranging from simple mathematical equations or statistical relationships to complex process-based models grounded in scientific principles. Representative models commonly employed in this domain include:

1) CH_4 MOD model

CH_4 MOD is a relative simpler process-based model designed to simulate methane emissions from rice paddies. It incorporates key scientific processes influencing methane production, with a primary focus on carbon sources within the rice field. These sources include organic matter derived from rice plants and externally applied organic amendments. Methane emission rates are influenced by the quantity of available carbon substrates, which are metabolized by methanogenic microbial communities. The model requires inputs on environmental and agronomic factors, including rice yield, cultivar characteristics, soil texture, soil temperature, and the type and amount of organic matter used for soil amendment.

2) DNDC-Rice model

The DNDC-Rice model is a process-based simulation tool that predicts the dynamics of carbon and nitrogen transformations in soil, emphasizing the interactions among carbon, nitrogen, and water. It has been specifically adapted to estimate GHG emissions from rice cultivation systems. The model integrates biogeochemical processes to simulate emissions of methane, nitrous oxide, and carbon dioxide, providing a comprehensive framework for assessing the environmental impact of rice farming practices.

These models exemplify widely used tools for estimating methane emissions from rice fields. However, effective application of such models requires extensive and high-resolution input data, including long-term datasets with appropriate temporal frequency.

Steps for applying GHG emission model in rice cultivation

The application of GHG emission models in rice cultivation across different scenarios requires model calibration, validation, emission prediction, and sensitivity and uncertainty analysis. Each of these steps plays a critical role in ensuring the reliability and applicability of the model outputs. For project development purposes, model users must clearly and transparently document the procedures undertaken in each step to ensure reproducibility and scientific rigor. A brief overview of these methodological components is provided below.

1) Input data requirements for initial site conditions, including baseline soil carbon content, climatic parameters, soil characteristics, crop variety, and field management practices.
2) Input specific data for GHG emission estimation in rice fields, including GHG emission rates and carbon inputs to the system, such as carbon from crop residues, and root biomass.
3) Soil biogeochemical processes to GHG emissions, including the decomposition of organic matter by methanogens and environmental conditions, such as soil moisture, temperature, and redox potential.
4) Simulation and prediction of GHG emissions from rice fields under defined scenarios. These scenarios may include variations in water management, management of crop residues, and fertilizer application.
5) Model calibration and validation using independent datasets. At minimum, the data should be divided into two sets: one for calibrating the model and another for validating its performance. This approach helps confirm that the model and input data are appropriate and capable of accurately predicting GHG emissions from rice fields under various simulated conditions.

Model uncertainty analysis

The application of GHG emission models necessitates the uncertainty analysis of model predictions. Uncertainty analysis is linked to data management and the computational processes involved in model construction. The steps in uncertainty analysis are as follows:

1) Data management
   - Including verifying the accuracy, completeness, and reliability of all input data used in model construction.

2) Evaluation of model predictions
   - Segmented analysis of predictions, such as random sampling to estimate both lower and upper bounds of predicted values.
   - Quantification of uncertainty, such as deterministic approximations, probabilistic estimations, or stochastic simulations

3) Testing and validation of probabilistic outcomes, such as testing the variability of model predictions under different conditions to assess the likelihood of various outcomes. Model validation is a critical component of this process, involving the application of the model to independent datasets to verify the accuracy of predictions and the robustness of uncertainty estimates.

The methods outlined above represent examples of approaches used in uncertainty analysis for GHG emission modeling. Given the complexity of these processes, multiple techniques may be employed depending on the modeling context. Therefore, selecting appropriate analytical tools and methodologies is essential to ensure that uncertainty assessments are both scientifically sound and credible.

Additional details on methods for assessing model uncertainty include:

1) Improved agricultural land management (VM0042 Version 2.1), VCS, 2024
2) Chapter 9: Model sensitivity and uncertainty analysis, Water Resources Systems Planning and Management: An Introduction to Methods, Models and Applications, Daniel P. Loucks and Eelco van Bee, Studies and Reports in Hydrology, UNESCO PUBLISHING, 2005, available online on: https://ecommons.cornell.edu/server/api/core/bitstreams/26197958-c64d-44a7-807b-9bd5e359a2a3/content.
3) Sensitivity and Uncertainty Analyses, Web-based Training on Best Modelling Practices and Technical Modelling Issues, Council for Regulatory Environmental Modelling (CREM), online available on https://19january2017snapshot.epa.gov/sites/production/files/2015-09/documents/mod8-saua-mod-final.pdf.

References

1) 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
2) 2006 IPCC Guidelines for National Greenhouse Gas Inventories
3) Gold Standard for the Global Goals: Methane Emission Reduction by adjusted Water management practice in rice cultivation Version 1.0
4) AMS-III.AU.: Methane emission reduction by adjusted water management practice in rice cultivation Version 4.0
5) UNFCCC CDM Tool-16 Project and leakage emissions from biomass (Section 6.2: Leakage due to diversion of biomass residues from other applications in year y)
6) Improved agricultural land management (VM0042 Version 2.1), VCS
7) NIAES, Guidelines for Measuring CH_4 and N_2O Emissions from Rice Paddies by a Manually Operated Closed Chamber Method Version 1, August 2015

Document History

Version	Amendment	Entry into force	Description
01	--	25 September 2024	-