Handbook of Monitoring, Reporting, and Verification for a Greenhouse Gas Mitigation Project with Water Management in Irrigated Rice Paddies

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Institute for Agro-Environmental Sciences, NARO, Japan

Handbook of Monitoring, Reporting, and Verification for a Greenhouse Gas Mitigation Project with Water Management in Irrigated Rice Paddies

Lead authors:

Kazunori Minamikawa (Japan)

Takayoshi Yamaguchi (Japan)

Takeshi Tokida (Japan)

Shigeto Sudo (Japan)

Kazuyuki Yagi (Japan)

Contributing authors:

Agnes Tirol-Padre (Philippines)

Dang Hoa Tran (Vietnam)

Amnat Chidthaisong (Thailand)

Evangeline B. Sibayan (Philippines)

Ali Pramono (Indonesia)

Miho Mochizuki (Japan)

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Institute for Agro-Environmental Sciences, National Agriculture and Food Research Organization (NARO)

Address: 3-1-3 Kannondai, Tsukuba, Ibaraki 305-8604, Japan

Tel: +81-29-838-8180, Fax: +81-29-838-8199, E-mail: niaes@naro.affrc.go.jp

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Contents

Background and concept of this handbook

Our climate is changing, with potentially severe implications for human life if we are unable to limit the global average temperature increase to less than 2°C above pre-industrial levels (Chabbi et al., 2017). Agriculture is an anthropogenic emitter of three major greenhouse gases (GHGs): carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Positive feedback due to global warming and rising atmospheric CO_2 concentrations is expected to increase GHG emissions from agricultural soils (e.g., Montzka et al., 2011; Tokida et al., 2010).

Rice is the staple food for the largest number of people on Earth (GRiSP, 2013). Increasing rice production to feed the growing human population is an urgent need, but rice cultivation also results in the emission of substantial amounts of CH_4 and account for 11% of anthropogenic CH_4 emissions (Ciais et al., 2013). Methane emissions from rice cultivation are especially troublesome for rice-producing countries in Asia; for example, they correspond to 12% of the national anthropogenic GHG emissions in Thailand (ONREPP, 2010) and 27% in Vietnam (MONRE, 2010).

Paddy irrigation leads to soil anoxia that creates reducing conditions and stimulates the activity of methanogenic archaea. Water management is one of the most promising options for mitigating CH_4 emissions from irrigated rice paddies because soil aeration during drainage events inhibits methanogenic activity. The IPCC (2006a) has designated 0.6 (error range: 0.46–0.80) and 0.52 (0.41–0.66) as the scaling factors (i.e., the ratios of CH_4 emissions associated with different practices to with continuous flooding) for single and multiple aeration during rice cultivation, respectively.

Although there have been advancements in the development of mitigation options in rice cultivation, there has not been sufficient implementation of those options by rice producers or incorporation of those options into administrative policies. There are three possible approaches to achieving widespread adoption of mitigation options by rice producers (Table 0.1). The voluntary approach is the most acceptable one for rice producers because it is directly linked to their (co-)benefits. However, there must be an upper bound to the mitigation achievable by nothing more than voluntary efforts. Through the semi-institutional approach, rice producers can obtain some financial incentive in the form of a government subsidy or private certification (e.g., added value through eco-labelling). Although the semi-institutional approach enables substantial mitigation of global warming, mitigation achieved with this approach cannot readily be registered to the national GHG inventory that is to be submitted to the United Nations Framework Convention on Climate Change (UNFCCC). The institutional approach mandates changes that are driven by carbon pricing (i.e., market mechanisms and a carbon tax) or Nationally Appropriate Mitigation Actions (NAMAs). Rice producers can gain economic incentives or can avoid taxes through participation in a mitigation project under a parent program (see Terms and definitional explanations for technical terms) that mandates rice producers to practice (additional) agricultural management. However, the methodology for implementing such a mitigation program in rice cultivation has not been well documented.

Table 0.1. Characteristics of three possible approaches to socially implement options for mitigating GHG emissions from rice cultivation.

	Voluntary	Semi-institutional	Institutional
Explanation	Get help from co-benefits/synergies for climate change adaptation, etc.	Domestic, voluntary subsidy, and certification systems	International or domestic carbon pricing and NAMA
Advantage	· No additional cost · Indirect financial incentive from improved products	· Financial incentive · Relatively easy documentation	· Financial incentive · Accountable to national GHG inventory
Drawback	· Limited number of options · Limited mitigation capacity	· Limited amount of subsidy · Limited purchasers · Difficult to be accounted in national GHG inventory	· Complicated documentation · Risks of low carbon price
Example	· Building up soil fertility (increase soil organic carbon) · Increasing N fertilizer use efficiency (decrease N_2O emission)	· A specific domestic subsidy · Eco-labelling · J-Credit (Japan Greenhouse Gas Emission Reduction/Removal Certification)	· CDM (Clean Development Mechanism) · JCM (Joint Crediting Mechanism) · Thai Rice NAMA

Note 1: The term "approach" does not mean "carbon market."
Note 2: An activity of the voluntary approach can be an activity of the semi-institutional approach or the institutional approach if approved.

MRV is a concept that integrates three independent processes of GHG emissions mitigation initiatives: monitoring or measurement (M), reporting (R), and verification (V) (Figure 0.1). Although each process should be independent of the others, MRV refers to a system that involves systematic integration of the three processes (IGES, 2011). The term MRV originally came from the Bali Action Plan, the negotiating text of the UNFCCC (UNFCCC, 2007) in Bali, Indonesia at the end of 2007. The basic understanding of the Bali Action Plan is that climate change mitigation actions—mainly reduction of GHG emissions—shall be implemented in a "measurable, reportable and verifiable" manner. This idea has had a significant impact on international negotiations since then.

In addition, use of market mechanisms is articulated under Article 6 of the Paris Agreement (UNFCCC, 2015a), which prescribes the use of emission reductions achieved overseas towards national emission reduction targets:

- Article 6.2: Internationally transferred mitigation outcomes (ITMOs) between authorizing Parties
- Article 6.4: A mechanism to contribute to mitigation and sustainable development.

This use of market mechanisms will accelerate the institutional spread of mitigation options through the development of MRV methodology under certain programs.

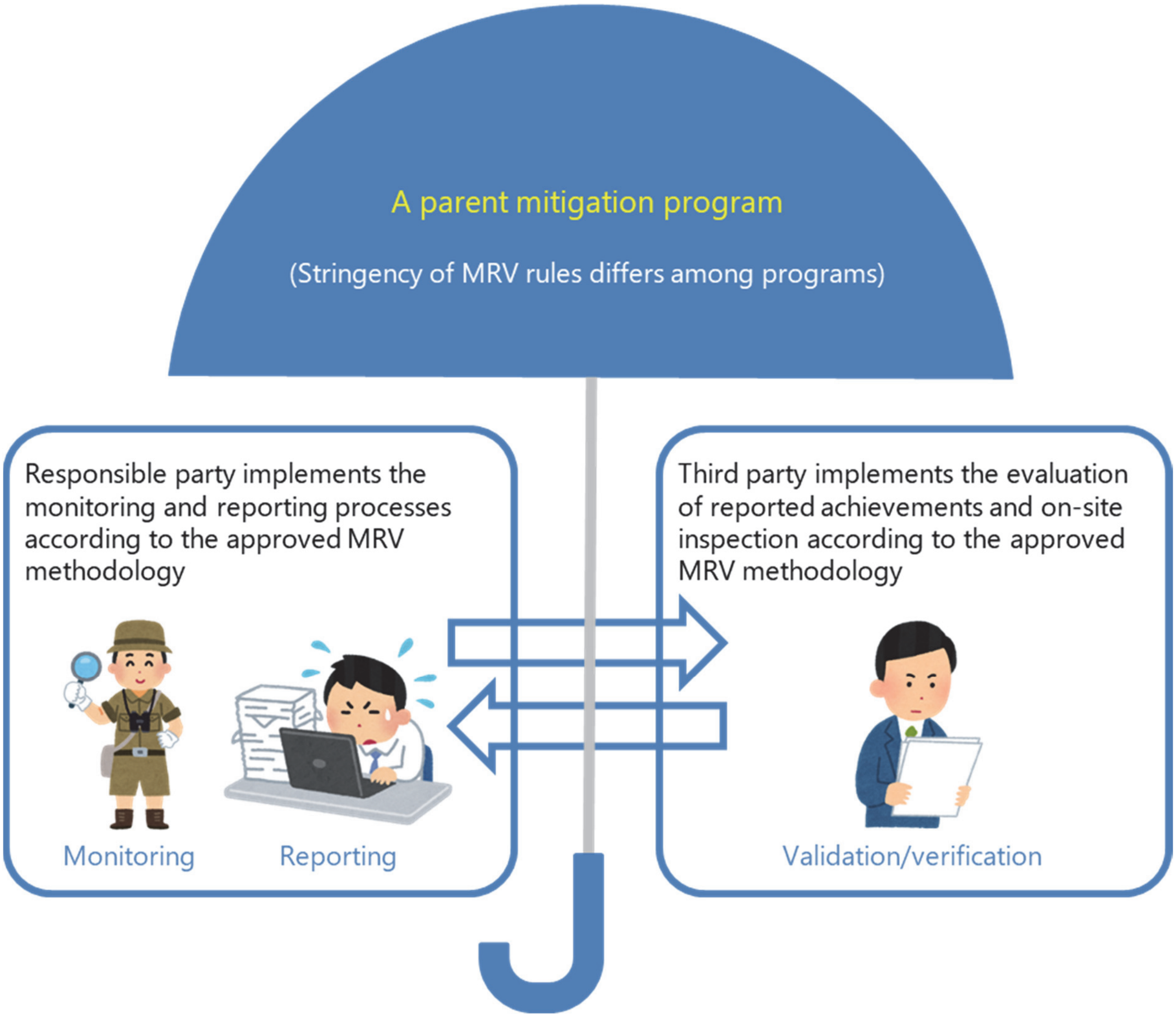

Figure 0.1. Conceptual diagram of MRV implementation under a parent mitigation program.

This handbook provides the persons who are engaged or interested in the development and implementation of MRV methodology for water management in irrigated rice paddies with (1) basic information about MRV, especially for quantifying GHG emissions and reductions and (2) updates on evolving issues facing these persons. This handbook should also be useful for developing other rice-related MRV methodologies, such as organic matter management. The simpler the methodology, the easier the MRV implementation; however, this handbook provides adequate background for the implementation of the most stringent MRV methodology in any mitigation program for paddy water management under any project. However, this handbook does not mention much about the basic concept of MRV (see Recommended readings). In the following chapters, this handbook provides basic information about MRV in the agricultural sector (chapter 1), applied information regarding project design for paddy water management (chapter 2), detailed methods of GHG quantification (chapter 3), and practical information on monitoring/reporting (chapter 4) and validation/verification (chapter 5). Each chapter starts with a summary and then describes the details.

In this handbook, the "M" of MRV refers to "monitoring"— a typical process carried out to ensure a GHG mitigation activity based on the project design developed under a parent program. In contrast, "measurement" is often used in UNFCCC-related matters to denote assessing stocks and inventories (e.g., CDM). This handbook uses "measurement" only in the context of GHG quantification before project implementation.

Terms and definitional explanations

This handbook consistently uses two auxiliary verbs hereafter to clarify requirements and recommendations for implementing MRV. The term "**shall**" is used to indicate what is required for a GHG mitigation project. The term "**should**" is used to indicate a recommendation, but not a requirement for all the projects.

This handbook uses technical terms found in the International Organization for Standardization (ISO) International Standards and also in the CDM (see Recommended readings for reference). Both terminologies often use the same term for the same meaning, but sometimes they do not. In the latter case, this handbook uses more common terms for the convenience of readers but notes cases where there might be confusion. This handbook aims to neither define nor propose new terms. The followings are definitional explanations and annotations for the technical terms used in this handbook (in parentheses, either ISO or CDM is indicated as the source of the definitive description).

Persons and parties concerned

- **Intended user** (ISO). Individual or organization identified by those reporting GHG-related information as the one who relies on that information to make decisions.
- **Responsible party** (ISO). Project participant in CDM. Person(s) responsible for providing information about GHGs and the supporting GHG-related information.
- **Third party** (ISO). Individual or organization independent from the responsible party that implements validation and/or verification.

Basic concepts

- **Program** (ISO) or (parent) mitigation program. Voluntary or mandatory international, national, or sub-national system or scheme that registers, keeps account of, or manages GHG emissions, removals, emission reductions, or removal enhancements outside the organization or project.
- **Project** (ISO) or mitigation project. Activity or activities that alter the conditions identified in the baseline scenario that cause reductions of GHG emissions or enhance GHG removal.
- **Baseline scenario** (CDM). Scenario for a project activity that reasonably represents the anthropogenic GHG emissions by sources that would occur in the absence of the project activity.
- **Project boundary** (CDM). The delineation of a geographical area of the project activity as determined in accordance with the applied methodologies and, where applicable, the applied standardized baselines.
- **Crediting period** (CDM). The period during which there were verified and certified GHG emission reductions or removals by sinks attributable to a project activity. The time period that applies to a crediting period for a project activity, and whether the crediting period is

renewable or fixed, is determined in accordance with MRV rules and requirements.

Specific concepts

- **Additionality** (CDM). Reduction potential of GHG emissions in ISO. The extent to which a project activity reduces anthropogenic GHG emissions below the level that would have occurred in the absence of the project activity.
- **Materiality** (ISO). The concept that an individual error or aggregate of errors, omissions, and misrepresentations could affect information about GHGs and could influence the intended decision of the user.
- **Leakage** (CDM). Affected GHG source, sink, or reservoir in the ISO. The net change of anthropogenic GHG emissions by sources that occurs outside the project boundary and that is measurable and attributable to the project activity.
- **Uncertainty** (ISO). Parameter associated with the result of quantification that characterizes the dispersion of the values that could be reasonably attributed to the quantified amount.
- **Level of assurance** (ISO). Degree of assurance that the intended user requires in a validation or verification. There are two levels of assurance: reasonable (i.e., high, but not absolute) and limited.

MRV principles

- **Relevance** (ISO). Select the GHG sources, GHG sinks, GHG reservoirs, data, and methodologies appropriate to the needs of the intended user.
- **Completeness** (ISO). Include all relevant GHG emissions and removals.
- **Consistency** (ISO). Enable meaningful comparisons in GHG-related information.
- **Accuracy** (ISO). Reduce bias and uncertainties as far as is practical.
- **Transparency** (ISO). Disclose sufficient and appropriate GHG-related information to allow intended users to make decisions with reasonable confidence.
- **Conservativeness** (ISO). Use conservative assumptions, values, and procedures to ensure that reductions of GHG emissions or enhancements of removal are not overestimated. In CDM, the term “transparent and conservative” is synonymous with conservative.

Recommended readings

Here we introduce books, articles, and documents that we recommend for reading before and during reading this handbook. As mentioned earlier, this handbook does not delve into general and fundamental rules and concepts of MRV. We therefore encourage readers to refer to the following references as necessary. We especially recommend UNFCCC (2014), American Carbon Registry (ACR) (2013), and California Air Resources Board (2015), which are listed on the next page and are required readings prior to development of MRV methodology for paddy water management.

General information

- ISO 14000 family - Environmental management.
  http://www.iso.org/iso/home/standards/management-standards/iso14000.htm
  - ISO 14064-1 (2006) Greenhouse gases — Part 1: Specifications with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals
  - ISO 14064-2 (2006) Greenhouse gases — Part 2: Specifications with guidance at the project level for quantification, monitoring, and reporting of greenhouse gas emission reductions or removal enhancements
  - ISO 14064-3 (2006) Greenhouse gases — Part 3: Specifications with guidance for the validation and verification of information about greenhouse gases
  - ISO 14605 (2013) Greenhouse gases — Requirements for greenhouse gas validation and verification to be used in accreditation or other forms of regulation
  - ISO 14066 (2011) Greenhouse gases — Competence requirements for greenhouse gas validation teams and verification teams
- UNFCCC (2017) Glossary: CDM terms (CDM-EB07-A04-GLOS, Version 09.1).
  https://cdm.unfccc.int/Reference/Guidclarif/glos_CDM.pdf
- IGES (Institute for Global Environmental Strategies) (2015) One Hundred Questions & Answers about MRV in Developing Countries.
  https://pub.iges.or.jp/pub/one-hundred-questions-answers-about-mrv-0
- VCS (Verified Carbon Standard) (2017a) VCS Standard (version 3.7).
  http://database.v-c-s.org/sites/vcs.benfredaconsulting.com/files/VCS_Standard_v3.7.pdf
- Bellassen, V., N. Stephan, M. Afriat et al. (2015) Monitoring, reporting and verifying emissions in the climate economy. Nat. Clim. Change 5, 319–328.
  http://www.nature.com/nclimate/journal/v5/n4/full/nclimate2544.html
  - Bellassen, V. and N. Stephan (2015) Accounting for Carbon: Monitoring, Reporting and Verifying Emissions in the Climate Economy, Cambridge Univ. Press. An enhanced book based on Bellassen et al. (2015).

Agriculture and forestry (non-paddy)

- Hirata, Y., G. Takao, T. Sato, J. Toriyama (2012) REDD-plus Cookbook. REDD Research and Development Center, Forestry and Forest Products Research Institute, Japan. https://www.ffpri.affrc.go.jp/redd-rdc/en/index.html
- REDD Research and Development Center (2013) Guidelines for Implementing REDD-plus (ver. 1.1). Forestry and Forest Products Research Institute, Japan. https://www.ffpri.affrc.go.jp/redd-rdc/en/reference/guideline/REDD+Guidelines_E_ver.1.1_20140327.pdf
- USDA (United States Department of Agriculture) (2014) Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory. https://www.usda.gov/oce/climate_change/estimation.htm
- VCS (2017b) AFOLU Requirements (version 3.6). http://database.v-c-s.org/sites/vcs.benfredaconsulting.com/files/AFOLU_Requirements_v3.6.pdf
- World Resources Institute (2014) GHG Protocol Agricultural Guidance: Interpreting the Corporate Accounting and Reporting Standard for the Agricultural Sector. http://www.ghgprotocol.org/standards/agriculture-guidance

Paddy rice

- UNFCCC (2014) AMS-III.AU: Methane emission reduction by adjusted water management practice in rice cultivation (small-scale methodology, version 4.0). https://cdm.unfccc.int/methodologies/DB/D14KAKRJEW4OTHEA4YJICOHM26M6BM
  - ➢ CDM precedents based on emission factors and scaling factors.
- Government of the Republic of the Philippines (2015) Adaptation and mitigation initiatives in Philippine rice cultivation: United Nations Development Programme. http://www.undp.org/content/undp/en/home/librarypage/environment-energy/mdg-carbon/NAMAs/adaptation-and-mitigation-initiatives-in-philippine-rice-cultiva.html
- ACR (2013) Voluntary Emission Reductions in Rice Management Systems (version 1.0). http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems
- California Air Resources Board (2015) Compliance Offset Protocol Rice Cultivation Projects. https://www.arb.ca.gov/cc/capandtrade/protocols/rice/riceprotocol2015.pdf
- Minamikawa et al. (2015) Guidelines for measuring CH_4 and N_2O emissions from rice paddies by a manually operated, closed-chamber method. National Institute for Agro-Environmental Sciences, Tsukuba, Japan. http://www.naro.affrc.go.jp/archive/niaes/techdoc/mirsa_guidelines.pdf
  - ➢ Regarded as the annex of this handbook for measurement-specific guidelines.

1. Introduction to MRV for paddy water management

1.1. Summary

This chapter provides readers with basic information about the implementation of MRV in the agricultural sector, especially for soil GHG emissions under paddy water management. This chapter reviews ongoing or emerging GHG mitigation programs and projects implemented in Asian countries.

- ✓ Development of MRV methodology in the agricultural sector, including rice cultivation, has been rapidly growing under mandatory or voluntary programs.
- ✓ Difficulties in MRV implementation for soil GHG emissions stem mainly from the inherently high spatiotemporal variability of nonpoint sources.

1.2. Ongoing or emerging GHG mitigation projects in the agricultural sector

Of the various ongoing agriculture-related GHG mitigation projects in Asia (Table 1.1), none target paddy water management. The approved CDM methodology for paddy water management (UNFCCC, 2014) was not registered by any countries as of January 2018. However, the tide is turning in our favor; the Paris Agreement introduces a provision of market mechanisms as one of the cooperative approaches (Articles 6; UNFCCC, 2015a). The Nationally Determined Contribution (NDC) submitted by many Asian countries involves agriculture-related activities. In particular, the Republic of Korea, Laos, and Japan have activities for reduction of CH_4 emissions from rice paddies in their NDCs. In addition, NAMAs that use Alternate Wetting and Drying (AWD; a multiple aeration practice) as the mitigation option are in the detailed phase of preparation in Thailand (Thai Rice NAMA; NAMA Facility, 2018) and in the preliminary phase with very limited implementation areas in the Philippines (AMIA; Government of the Republic of the Philippines, 2015) as of January 2018.

Table 1.1. Examples of ongoing agriculture-related GHG mitigation projects in Asian countries.

Project/subject	Parent program	Country
Biogas	CDM	Cambodia, China, Indonesia, Laos, Philippines, Thailand
Biomass	CDM	Cambodia, India, Indonesia, Philippines, Thailand
Agriculture (fertilizer and carbon sequestration)	T-VER (Thailand Voluntary Emission Reduction)	Thailand
Agriculture (mangrove and peatland)	VCS	China, India, Indonesia
Agriculture (fertilizer and manure)	J-Credit	Japan

1.3. Workflow to implement MRV for a mitigation project

Figure 1.1 shows a typical workflow to implement MRV for a particular target. The sources and sinks of GHG emissions are relatively easy to identify and to accurately quantify in a (semi-)closed system compared to in an open system such as agricultural soils. Detailed procedures for the monitoring and reporting processes implemented by a responsible party are listed in Table 1.2. Also, Table 1.3 lists detailed procedures for the verification process implemented by a third party, such as an auditing company certified by the program board/committee. The same procedure (Table 1.3) is true for the validation process, but in the case of CDM, the validation process also includes an assessment of baseline practices, consultation with local stakeholders, and environmental impact assessment.

Figure 1.1. Typical workflow to implement MRV for a particular project (left) and the players (right).

Table 1.2. Typical procedure for the monitoring and reporting processes.

Step	Procedure
1	Distinguishing project boundary
2	Identifying emission sources, sinks, and reservoirs
3	Determining how to monitor emissions/activities
4	Establishing monitoring system
5	Monitoring and calculating emissions/activities
6	Reporting emissions/activities

Modified from MOE (2013).

Table 1.3. Typical procedure for the verification process.

Step	Procedure
1	Understanding the outline of mitigation project to be verified
2	Assessing the potential risks of the errors in monitoring and calculation
3	Formulating action plan for verification
4	Implementing the action plan
5	Evaluating the result of the implementation
6	Forming opinions from the evaluation
7	Making verification report and reviewing it
8	Publishing the report

Modified from MOE (2013).

The World Resources Institute (2014) has identified the following six challenges for implementation of MRV in the agricultural sector:

1. The impact of environmental factors on agricultural GHG emissions, which complicates the separation of anthropogenic contributions from natural variability.
2. Spatial variability in agricultural GHG emissions due to varying environmental conditions across landscapes.
3. Temporal variability in background agricultural GHG emissions, which complicates setting and tracking progress toward emission reduction goals.
4. Carbon sequestration and accounting for changes in the management and ownership of different carbon pools.
5. Delayed effects of agricultural activities on agricultural GHG emissions.
6. Organizational structures and management practices specific to the agricultural sector.

All of the six challenges surely apply to a project for paddy water management. The nature of (1) non-point sources and (2) heterogeneity make each MRV procedure especially complicated for soil GHG emissions compared to a (semi-)closed system.

1.4. Notes on the six MRV principles

The six MRV principles (see Terms and definitional explanations) shall be understood well before implementing a mitigation project. Here we describe the interpretation and consideration of each principle when it is applied to a project for paddy water management. The limited budget that can be used for implementing MRV hinders compliance with all the principles. In addition, a NAMA project is subject to less stringent requirements than a project based on market mechanisms.

Relevance and completeness. The responsible party should take account of all the sources/sinks of the three major GHGs (CO_2, CH_4, and N_2O) within the project boundary and all the sources of leakage outside the boundary. For example, consideration of the trade-offs between CH_4 emissions reduction and N_2O emissions during drainage events and between CH_4 emission reduction and soil carbon loss (i.e., enhanced aerobic decomposition during drainage events) depends on the set materiality (e.g., a source that accounts for <10% of the total GHG emissions can be conservatively excluded).

Consistency and transparency. The responsible party should consider the units of GHG emissions and agricultural activities to better compare them with emissions from other agricultural systems, such as livestock and upland crops. It is common to use the IPCC's 100-year Global Warming Potential (GWP) [the latest values are provided in Myhre et al. (2013)] for calculating CO_2-equivalent emissions among different GHGs. Methods used and (raw-)data obtained for GHG calculations should be clearly disclosed. However, the version of the IPCC's GWP values needs to be consistent under the parent program (and even among programs).

Accuracy and conservativeness. The uncertainties associated with calculated GHG emissions and additionality (i.e., emission reduction by a project) are unavoidable because of the high spatiotemporal variability of soil GHG emissions. Moreover, error propagation from a series of monitoring and reporting steps may yield substantial uncertainty that offsets the obtained additionality. Biases (i.e., systematic errors) in the monitoring process should be minimized by adopting appropriate methods. The VCS (2017a) noted that accuracy should be pursued as far as possible, but the hypothetical nature of baselines, the high cost of monitoring of some types of GHG emissions and removals, and other limitations make satisfactory accuracy difficult to attain in many cases. In these cases, conservativeness may serve as a moderator to accuracy to maintain the credibility of project and program GHG quantification (VCS, 2017a).

2. Development of basic project design

2.1. Summary

This chapter introduces the information required for development of the project design for paddy water management by the responsible party.

- ✓ The responsible party shall identify all the GHG sources, sinks, and reservoirs and select target GHGs and their sources, sinks, and reservoirs after taking materiality into consideration.
- ✓ The responsible party shall select the project area candidate where paddy water management is feasible in respect of natural and artificial conditions for irrigation and drainage.
- ✓ The project area should follow administrative boundaries as well as natural boundaries to facilitate collection of necessary information about agricultural activities.
- ✓ The responsible party shall know the minimum duration of the crediting period for the local conventional cropping system.
- ✓ Baseline/conventional water management shall be accurately identified from the past record in the project area, the fields currently surrounding the project, and the crop calendar.
- ✓ Project water management shall consider not only GHG emissions but also rice physiology to achieve the same rice productivity as the baseline scenario.

2.2. GHG sources, sinks, and reservoirs

Is CH_4 emitted from soil the sole target GHG and the sole source in a project for paddy water management? Here we discuss the kind of target GHGs and the time and place of their emission, consumption, and storage in the project.

Three GHGs, namely CH_4, N_2O, and CO_2, are generally exchanged between paddy soil and the atmosphere through various pathways (Table 2.1). Machinery fuel consumption is also a source of CO_2 emissions. The responsible party shall first identify all the sources, sinks, and reservoirs of the three GHGs. The responsible party shall then determine target GHGs and their exchange pathways taking into consideration the materiality designated in the parent program. If the relative contribution of a certain GHG source to all the sources is less than the set threshold (e.g., 5% or 10%), the responsible party is allowed to conservatively exclude it from the calculation of total GHG emissions (see also subchapter 3.6). For example, the contribution of N_2O to the GWP of CH_4 and N_2O is usually less than 5%. However, in cases of (1) soils with relatively low potential of CH_4 emission (e.g., sulfate acid soils and volcanic ash soils), (2) high rates of N fertilizer application, and (3) N fertilizer application during drainage events, the contribution of N_2O to the CH_4+N_2O GWP may exceed 5%. Consequently, the responsible party should prepare a preliminary dataset that summarizes the magnitude and pathway of the three GHG exchanges in a candidate area or soil type.

Table 2.1. Major sources, sinks, and reservoirs of the three GHGs exchanged in rice paddies.

	Source	Sink	Reservoir
CH_4	Wet/flooded soil	Dry soil	None
N_2O	Drained soil, leakage (atmospheric N deposition, N leaching/runoff)	None	None
CO_2	Soil, fuel	Plants, soil[†]	Soil[†]

[†] Soil can be a CO_2 sink when soil organic carbon (SOC) storage is not saturated, whereas soil is just a CO_2 reservoir (i.e. no apparent change) when SOC storage is saturated.

CH_4 is the main target GHG in the project for paddy water management. In addition to the rice-growing season, CH_4 may be emitted during the fallow season if the soil is wet or flooded. CH_4 consumption in the dry, fallow season is generally negligible compared to the emission in the growing season. In the case of specific soils that have low CH_4 emission potential, paddy water management may instead increase the total GHG emissions compared to those from continuous flooding due to the tradeoff N_2O emission (e.g., Chidthaisong et al., 2018) and the CH_4 emission peak during drainage events (i.e., release of entrapped CH_4).

N_2O is usually the second targeted GHG after CH_4. As mentioned above, N_2O emissions often occur just after N fertilizer application and during drainage events in the rice-growing season. From agronomic and environmental aspects, N fertilizer application should be practiced under flooded conditions to increase N use efficiency by rice plants and to avoid unnecessary N_2O emission. Infrequent GHG measurements may miss temporary (less than a few days) N_2O emission spikes and cause an inaccurate calculation of total emissions (Minamikawa et al., 2015). In addition, indirect N_2O emissions associated with N leaching and runoff can result in leakage that occurs outside the project boundary.

CO_2 is often overlooked in the calculation of the total GHG emissions. Although the balance of CO_2 exchanges in a rice paddy is believed to be stable (i.e., carbon neutral), water management may enhance aerobic decomposition of soil organic carbon (SOC) compared to SOC decomposition under anaerobic flooded conditions. For example, Nishimura et al. (2015) have reported that a substantial amount of CO_2 emission occurs during temporary drainage events in the rice-growing season. In contrast, 3 years of field monitoring in four Asian countries demonstrated that AWD did not reduce topsoil SOC concentrations compared to those under continuous flooding (Chidthaisong et al., 2018; Setyanto et al., 2018; Sibayan et al., 2018; Tirol-Padre et al., 2018; Tran et al., 2018). Temporal (inter-annual) variations in SOC storage should therefore be checked at least during the crediting period of the project to demonstrate the absence (or presence) of SOC loss.

CO_2 emissions from machinery within the project boundary may differ between baseline and project practices (e.g., additional fuel consumption by pumps). In contrast, CO_2 emissions from irrigation infrastructure outside the boundary (e.g., upstream dams) would not differ. This is true for GHG emissions during post-harvest handlings, fertilizer production, etc. (e.g., Hokazono and Hayashi, 2012; Brodt et al., 2014). After preliminarily quantification of all the GHG sources, sinks, and reservoirs, the responsible party should determine whether to include or exclude such CO_2 emissions after taking into consideration the materiality.

2.3. Feasibility of paddy water management

Rice paddies are generally located in an area such as lowlands where irrigation water is plentiful during the rice-growing season. If the amount of irrigation water fluctuates or is insufficient, especially in the dry seasons, rice producers are reluctant to practice water management to avoid drought stress on rice plants.

Paddy water management essentially requires control of the level of the surface water. The amount of available irrigation water is primarily governed by regional precipitation and competition for its use and distribution among other sectors (industry and households). Even if the availability of water is limited during the dry seasons, water management can be forced on all downstream fields by upstream dams. At the field scale, soil physical properties that affect vertical water percolation contribute to the control of the surface water level. At the landscape scale, differences in elevation (i.e., topography) among rice paddies in the project area can be a controlling factor (e.g., Yamaguchi et al., 2017). Nelson et al. (2015) assessed the spatiotemporal pattern of climate suitability for the AWD irrigation technique in the Philippine province of Cagayan using the water balance model that they developed and drew a suitability map for AWD. They found that within a substantial area during the wet season rice was climatically suitable for implementation of AWD, in contrast to the notion that AWD is not suitable during the monsoon season because of excessive precipitation that prevents drainage. The feasibility of drainage is therefore critical to effective implementation of water management during wet seasons.

Irrigation infrastructure, including upstream dams, ditches, and the water intake and outlet of a field, is also crucial for precise adjustment of surface water levels. For example, in the An Giang province of Vietnam's Mekong delta, full dike systems in combination with pumps to irrigate from and drain to neighboring channels enable rice producers a triple rice cropping, including a wet season crop (Figure 2.1; Yamaguchi et al., 2016). Such infrastructure may overcome the lack and/or surplus of regional and seasonal precipitation and thus expand the opportunity and area for implementation of a paddy water management project, albeit with additional cost.

Water management during the fallow season can also be the target of a mitigation project (but not as the sole target). Because wet/flooded soil conditions during fallow periods can cause substantial CH_4 emissions, depending on weather conditions (e.g., Cai et al., 2003; Fitzgerald et al., 2000), keeping the soil dry is worthwhile. Furthermore, dry soil conditions in the fallow season also reduce CH_4 emissions in the subsequent rice-growing season (e.g., Shiratori et al., 2007). This is especially true in areas with multiple rice cropping, where the interval between the two rice seasons is short (see Table 3.3), and in areas with snow cover and/or low temperatures, where rice residue decomposition is delayed. The feasibility of water management during fallow seasons should be considered in such areas after taking into account the trade-off N_2O emissions during the periods when the paddies are temporarily drained.

An evolving issue regarding the feasibility of paddy water management is the co-benefits and trade-offs associated with reduction of GHG emissions. A win-win relationship with water conservation can be achieved by paddy water management, but excessive soil drainage may reduce rice productivity. In acid sulfate soils, avoiding hydrogen sulfide toxicity may increase rice productivity (e.g., Yamaguchi et al., 2017). Compared with the baseline scenario, a project should ideally obtain the same level of rice grain yield. Possible negative side effects include contamination with heavy metals (arsenic), weed growth, and changes in biota, depending on the soil properties and location. For example, the forest MRV system REDD-plus requires the conservation of biodiversity within the project boundary as a safeguard (Hirata et al., 2012). Although co-benefits are welcome, possible co-benefits and trade-offs should be carefully discussed before project implementation.

Figure 2.1. A dike system established in An Giang province, Vietnam. (Top left) a bank dividing a canal and fields. (Top right) intake pump for irrigation water to fields. (Bottom) large pumps for drainage to channel.

2.4. Spatial boundary

There are several restrictions in determining the project boundary as well as the feasibility of water management, as mentioned above. First, the responsible party should be cognizant of natural and societal boundaries. Those boundaries involve topography (e.g., catchment), administrative sections, and the minimum unit of rice production (e.g., group and shared infrastructure). Although only natural factors would ideally need to be considered for simplicity, societal factors are in fact not negligible. For example, in the case of An Giang province, Vietnam, many rice paddies are located in the same zone surrounded by a dike system (see Figure 2.1), and thus rice producers have to follow an operation schedule based on the sharing of large pumps for irrigation and drainage (Yamaguchi et al., 2017). Furthermore, in the context of facilitating reporting procedures, statistical data on agricultural activities (e.g., harvested area and fertilizer dose) are often collected based on administrative units. Another restriction is the potential reduction of GHG emissions per area. The responsible party shall consider the minimum accounting area as well as the minimum accounting period (see Tables 3.6 and 3.7).

An evolving issue regarding the spatial boundary of the project is whether zones of exception within the boundary are allowable or not. For example, such areas might involve zones/soils with low CH_4 emission potential and areas with uncontrollable irrigation and drainage. Such zones may be identified after project implementation. The chance of revising project design during the crediting period would be important in making the project successful.

There should be an economy of scale for a project area mainly because of the dilution of fixed MRV costs. In addition, the total MRV cost depends on the methodologies used for the monitoring of GHG emissions and agricultural activities. An improvement of monitoring technology, such as remote sensing and automated sensors/loggers, will therefore increase the spatial scale of a project.

2.5. Crediting period

The period covered by a project is primarily constrained by (1) the length of a single rice-growing season and (2) the additionality (GHG emission reduction) that can be achieved in one season/year. For example, the California Air Resources Board (2015) uses 10-year crediting periods for its paddy water management projects.

Rice producers grow rice once, twice, or three times a year (Laborte et al., 2017). Of course, the responsible party can set a single rice-growing season as the crediting period. One year, including both the growing season(s) and fallow season(s), would be the best minimum duration for the following two reasons. First, the implementation of project water management may change GHG emissions in the subsequent fallow season because the soil will be relatively dry compared to the baseline scenario. Second, keeping soil dry during the fallow season can reduce CH_4 emission in the subsequent rice-growing season (Kang et al., 2002; Shiratori et al., 2007). Such 'carry-over' effects are relevant to project assessment and should be considered in the determination of the minimum crediting period. When including the SOC pool as a GHG source/sink/reservoir in the GHG calculation, the crediting period shall be extended compared to a project targeting only CH_4 and N_2O because of the risk of non-permanence (VCS, 2017b) of SOC decomposition after the period (e.g., enhanced CO_2 emissions by land use change from paddy rice to upland crops).

An evolving issue regarding the crediting period is whether a change in the number of rice cultivation from the original design is allowable or not. In tropical and subtropical regions, rice producers may grow rice multiple times per year without considering the annual frequency (e.g., usually three times per year but sometimes five times per two years). Another possible issue is that a rice cultivation may have to be canceled due to extreme weather events, such as El Niño or La Niña. MRV rules for such exceptional cases should be prepared in the project design.

2.6. Baseline practice of paddy water management

The responsible party should review paddy water management practices reported in the latest national GHG inventory report or the latest national communication (UNFCCC, 2017) in the country of interest because inconsistencies may cause incorrect representation of the project effort. Characteristics of conventional water management in the area, including management in the fallow season, can be identified from practices during the past several years in the project area and surrounding paddy fields, as well as from the local rice crop calendar (if available). Even if the conventional practice is claimed to be continuous flooding, the actual surface water level may fluctuate because of low-frequency adjustments or for other reasons. If the conventional practice is already single/multiple aeration that can reduce CH_4 emissions sufficiently, there is very limited room for development of a mitigation practice.

An evolving issue is the spatiotemporal variation in conventional/baseline water management within the project boundary. Basically, in one project area, all paddies should follow the same baseline practice; however, there may be some exceptions for various reasons. In addition, for a long-term (e.g., 10 years) project, conventional management in the area may change during the crediting period because of adaptation to climate change, the development of irrigation infrastructure, and empirical recognition by the rice producers of the positive effect of the project on rice productivity (if applicable). Another issue is the connection between water management and other agricultural practices, such as fertilizer application and use of agrochemicals. N fertilizer should be applied during flooded periods (i.e., not during drainage events) to minimize N_2O emissions, which may change the rate and timing of N fertilizer application. For example, the CDM methodology for paddy water management allows a change in the N fertilizer scheme (rate and timing) from the conventional scenario to offset possible drought stress on rice phenology, especially in the tropics (UNFCCC, 2014). A strategy that can offset the negative effects of project water management should be fully discussed before implementing a project.

2.7. Agronomic requirements for project water management

One of the greatest concerns of rice producers regarding the implementation of project water management is the possibility of a decrease in rice productivity due to drought stress, especially during dry seasons. However, recent field studies in southeast Asian countries have demonstrated that AWD did not significantly decrease rice grain yield compared to continuous flooding (Chidthaisong et al., 2018; Setyanto et al., 2018; Sibayan et al., 2018; Tirol-Padre et al., 2018; Tran et al., 2018). Note that this guidebook focuses on rice cultivars suited for normal wet/flooded soil conditions. New cultivars suited for dry soil conditions (e.g., aerobic rice) are not discussed here.

Rice plants demand water, especially in the rooting and flowering stages. Figure 2.2 shows the typical schedule of water management practiced in Japanese irrigated rice paddies. Such a schedule is effective in reducing CH_4 emissions without adversely affecting yields and thus can be applied in other countries, as demonstrated in the above field studies. In addition, N fertilizer should be applied under flooded conditions, not during drainage events, to enhance N use efficiency by rice plants as well as to reduce N_2O emission.

Figure 2.2. Typical practice of paddy water management in Japan. Midseason drainage (MD) at the rice-tillering stage for a period of 5–7 days is followed by intermittent irrigation (IM) that involves repeated periods of alternate flooding and drying, each for a few days.

3. Calculation of GHG emission reduction

3.1. Summary

This chapter introduces basic and practical information that will enable the responsible party to calculate the additionality obtainable through the project using the emission factor (EF) system. The modeling approach for GHG calculations is discussed in the last subchapter.

- ✓ Data essential for CH_4 emission calculation are (1) the EF and SF_w (scaling factor for water management), (2) the area of the project, and (3) the duration of the crediting period.
- ✓ The responsible party shall approximately calculate in advance the length and width of a project necessary to make the project economically profitable.
- ✓ The EF and SF_w of CH_4 for project water management should be obtained for the project area to maximize the additionality.
- ✓ The responsible party should monitor and report long-term SOC changes during the crediting period to confirm the existence or absence of the effect of these changes on the total GHG emission.
- ✓ Uncertainties associated with the calculated results that stem from both GHG monitoring and agricultural activity should be quantified to meet the principle of conservativeness.
- ✓ Model simulation is a sophisticated approach for GHG calculations in a wide area, but it requires many input parameters.

3.2. Data essential for calculating CH_4 emissions

The emission of CH_4 can be calculated by multiplying the area-specific EF by the SF_w, the area, and the period (see Equation 3.1). To accurately calculate the potential of the project to reduce GHG emissions, the responsible party shall collect data essential for the calculation. During this exercise, the responsible party should pay attention to the MRV principles, such as accuracy, transparency, and conservativeness.

Table 3.1. Agricultural activity data essential to calculate CH_4 emissions from a project.

Activity	How to monitor
Project area	Remote sensing, local statistics, and location survey. Soil classification map and local crop calendar are useful to identify the spatial differences within the project boundary.
Crediting period	Fixed (e.g., 5 years) or unfixed (e.g., 10 rice seasons) term.

Agricultural activity data that are essential for the calculation are the project area and the duration of the crediting period (Table 3.1). If there are no differences in factors such as baseline water management, soil type, rice cultivar, and cropping calendar among the different zones within the project boundary, it is relatively easy to estimate the area using remote sensing and/or local statistics. However, if there are substantial spatial differences in the above-mentioned factors, the responsible party should prepare a breakdown of the data as well as a breakdown of the EF and SF_w. The duration of the crediting period may differ among seasons when assigned to a single rice-growing season or a single cultivation year, because it depends on weather conditions. However, the minimum unit of the crediting period should be 1 year (see subchapter 2.5).

3.3. Calculation of reduction of CH_4 emissions and the economic incentive

The responsible party calculates in advance the potential additionality (i.e., reduction of GHG emissions) achieved through the project and its economic incentive so that unprofitable projects are weeded out based on market mechanisms. The actual CH_4 emission reduction is also calculated during and after the crediting period. In NAMAs, it is also expected that the effect of a project will be maximized: the greater the area-scaled CH_4 emission, the greater the potential for emission reduction. We introduce here a detailed calculation and provide some examples assuming realistic magnitudes of CH_4 emissions and carbon prices. In this subsection, we assume the differences in N_2O emissions and CO_2 exchanges between project and baseline practices to be negligible.

The default CH_4 emission factor of the IPCC Tier-1 approach is 1.30 kg CH_4 ha^{-1} d^{-1} with error range 0.80–2.20 (IPCC, 2006a). This emission factor can be converted to a yearly factor (kg CH_4 ha^{-1} y^{-1}) by multiplying by the total number of days of the rice-growing season(s) in a year. Tables 3.2 and 3.3 show the IPCC default scaling factors for water management in the rice-growing season and fallow season, respectively. The responsible party can estimate the CH_4 emission approximately with the following equation:

$$E = EF_{Tier1} \times SF_w \times SF_p \times SF_o \times SF_{s,r} \times A \times Y \times GWP \quad \textbf{(Equation 3.1)}$$

where E is the total emission (kg CO_2-eq ha^{-1}); EF_{Tier1} is the yearly emission factor (kg CH_4 ha^{-1} yr^{-1}); SF_w is the scaling factor for the water regime during the rice-growing season; SF_p is the scaling factor for the water regime during the fallow season; SF_o is the scaling factor for organic amendment; $SF_{s,r}$ is the scaling factor for the soil type, rice cultivar, etc. (if available); A is the area (ha); Y is the duration of the project (yr); and GWP is the global warming potential (kg CO_2 kg CH_4^{-1}).

The adjusted CH_4 emission scaling factor for organic amendments is calculated using the conversion factors listed in Table 3.4 as follows:

$$SF_o = (1 + \Sigma_i\, ROA_i \times CFOA_i)^{0.59} \quad \textbf{(Equation 3.2)}$$

SF_o is the scaling factor for the type and amount of organic amendment applied; ROA_i is the application rate of organic amendment i in dry weight for straw and fresh weight for others (t ha^{-1}); $CFOA_i$ is the conversion factor for organic amendment i; 0.59 is an exponent with an uncertainty range of 0.54–0.64.

Table 3.2. Default CH_4 emission scaling factors for disaggregated case of irrigated water regimes (IPCC, 2006a).

Water management	Scaling factor	Error range
Continuous flooding	1	0.79–1.26
Single aeration	0.6	0.46–0.80
Multiple aeration	0.52	0.41–0.66

Table 3.3. Default CH_4 emission scaling factors for disaggregated case of water regimes during fallow season (IPCC, 2006a).

Water management	Scaling factor	Error range
<180 days non-flooded	1	0.88–1.14
>180 days non-flooded	0.68	0.58–0.80
>30 days flooded	1.90	1.65–2.18

Table 3.4. Default CH_4 emission conversion factors for organic amendments (IPCC, 2006a).

Organic amendment	Conversion factor	Error range
Straw incorporated <30 days before cultivation	1	0.97–1.04
Straw incorporated >30 days before cultivation	0.29	0.20–0.40
Compost	0.05	0.01–0.08
Farm yard manure	0.14	0.07–0.20
Green manure	0.50	0.30–0.60

If the area-specific yearly emission factor that takes into account the effects of agricultural practices other than water management during the rice-growing season (EF_{Tier2}; kg CH_4 ha^{-1} yr^{-1}) is already available for the candidate area, the responsible party can calculate more accurately CH_4 emission with the following equation:

$$E = EF_{Tier2} \times SF_w \times A \times Y \times GWP \quad \textbf{(Equation 3.3)}$$

where it is assumed that agricultural practices other than water management during the rice-growing season are the same between project and baseline.

In addition, it is possible to designate an area-specific yearly EF for project water management ($EF_{Tier2\text{-}project}$) if data are available (see subchapter 3.4 for developing area-specific EFs and SF_ws). In that case, the responsible party does not need to use the IPCC SF_w (Table 2.1) and thus can calculate more accurately CH_4 emissions from the project as follows:

$$E = EF_{Tier2\text{-}project} \times A \times Y \times GWP \qquad \textbf{(Equation 3.4)}$$

where $EF_{Tier2\text{-}project}$ can be expressed as the product of EF_{Tier2} and $SF_{w\text{-}project}$.

Finally, the potential for reduction of CH_4 emissions can be derived by subtracting the calculated project emissions from the calculated baseline emissions. Table 3.5 shows examples of the area-scaled emission reduction calculated using Equation 3.1. To be a profitable project with substantial reduction of CH_4 emissions, the responsible party shall consider both area and period based on the potential of area-scaled reduction of CH_4 emissions.

Table 3.5. Calculated reduction of CH_4 emissions under various scenarios of baseline emission and water management using the IPCC default scaling factors for irrigated water management (kg CH_4 ha^{-1} yr^{-1}).

Baseline emission from CF	100	250	500	750	1000	1500
Emission reduction by SA	40	100	200	300	400	600
Emission reduction by MA	48	120	240	360	480	720

CF, continuous flooding; SA, single aeration (SF_w = 0.6); MA, multiple aeration (SF_w = 0.52).

One of the greatest concerns for the responsible party is how much economic return project implementation can achieve. The greatest uncertainty factor with respect to the amount of money would be the carbon price. The observed carbon prices span a wide range from less than 1 to 137 USD t CO_2-eq^{-1}; however, about three-fourths of surveyed emissions are priced at less than 10 USD t CO_2-eq^{-1} (World Bank and Ecofys, 2016). Rogelj et al. (2017) estimated the global average carbon price in 2030 at 3–26 USD t CO_2-eq^{-1}, depending on the socio-economic scenarios used to achieve NDC targets—the higher the projected atmospheric CO_2 concentration, the higher the carbon price. Tables 3.6 and 3.7 show examples of the estimated economic incentive for selected carbon prices achieved by a specified reduction of CH_4 emissions. The profit threshold varies between regions, depending on factors such as the rice production cost. Another variable, the MRV cost, will also constrain the expected return and thus the motivation for project implementation.

Table 3.6. Estimated economic incentive for an emission reduction of 100 kg CH_4 ha^{-1} yr^{-1} under various combinations of carbon price, project area, and crediting period (USD).

Carbon price (USD t CO_2-eq^{-1})	1	10	50	100
1 year and 1 ha	2.5	25	125	250
1 year and 10 ha	25	250	1250	2500
1 year and 50 ha	125	1250	6250	12500
5 years and 1 ha	12.5	125	625	1250
5 years and 10 ha	125	1250	6250	12500
5 years and 50 ha	625	250	1250	2500
10 years and 1 ha	25	250	1250	2500
10 years and 10 ha	250	2500	12500	25000
10 years and 50 ha	1250	12500	62500	125000

Note: Using the 2007 IPCC GWP of 25 for CO_2 conversion (i.e., 100 kg CH_4 = 2.5 t CO_2-eq).

Table 3.7. Estimated economic incentive for an emission reduction of 500 kg CH_4 ha^{-1} yr^{-1} under various combinations of carbon price, project area, and crediting period (USD).

Carbon price (USD t CO_2-eq^{-1})	1	10	50	100
1 year and 1 ha	12.5	125	625	1250
1 year and 10 ha	125	625	6250	12500
1 year and 50 ha	625	6250	31250	62500
5 years and 1 ha	62.5	625	3125	6250
5 years and 10 ha	625	6250	31250	62500
5 years and 50 ha	3125	1250	6250	12500
10 years and 1 ha	125	1250	6250	12500
10 years and 10 ha	1250	12500	62500	125000
10 years and 50 ha	6250	62500	312500	625000

Note: Using the 2007 IPCC GWP of 25 for CO_2 conversion (i.e., 500 kg CH_4 = 12.5 t CO_2-eq).

3.4. Development of area-specific CH_4 emission factors

Area-specific EFs and SF_ws for project water management should be obtained for the project area to maximize the additionality. This method corresponds to the IPCC Tier-2 approach (see Equations 3.3 and 3.4). If the IPCC default Tier-1 EF and SF_w described in subchapter 3.3 are used, the calculated CH_4 emissions and the resultant additionality may be inaccurate for the project area. Based on the principle of conservativeness, the responsible party should adopt the most conservative values to avoid overestimating the additionality. This is the main reason why the responsible party should measure GHG emissions on site. However, as mentioned in subchapter 3.6, some parent programs do not require adherence to this principle.

Figure 3.1 shows the decision tree for selecting the EF and SF_w for CH_4 emissions in a project area. There are two ways to obtain area-specific EFs and SF_ws. One way is to use an EF and SF_w already obtained in the project area. In this case, if published data on CH_4 emissions or area-specific EFs and SF_ws are already available, the responsible party can use them instead of obtaining them from on-site measurements. The responsible party should calculate the uncertainty in the published GHG data to satisfy the principle of conservativeness, even if the original paper did not provide the details (see subchapter 3.6 for details). In CDM, it is also possible to apply standardized values approved by the CDM Executive Board for a specific country/region (e.g., for the Philippines, UNFCCC, 2015b) under the approved CDM methodology for paddy water management (UNFCCC, 2014).

Another way is to make on-site measurements of EF and SF_w in the project area before project implementation. A closed-chamber method enables the responsible party to compare GHG emissions between the project and baseline water management in a relatively small area (e.g., 5 m × 5 m). However, this approach requires a side-by-side comparison because of the heterogeneities of soil and agricultural activity. Therefore, the number of GHG sampling points within the project area should be increased as it becomes larger. If the responsible party does not yet know the degree of heterogeneity, the GHG sampling points should be set more conservatively. For example, Sass et al. (2002) reported that the spatial variability of CH_4 emissions in a rice paddy was within ±20% of the actual value. For the detailed protocol of the closed-chamber method, see Minamikawa et al. (2015).

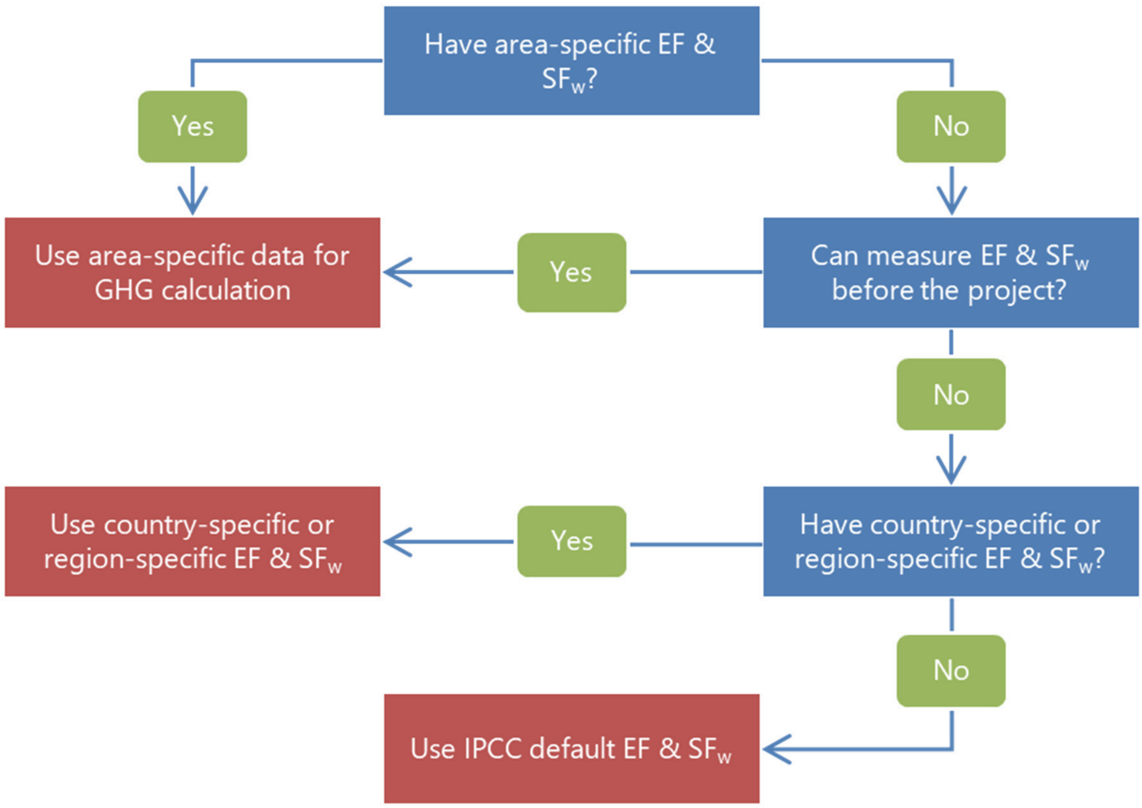

Figure 3.1. Decision tree for the selection of EF and SF_w of CH_4 emissions.

There is one evolving issue regarding the area-specific EF and SF_w. As already explained, GHG emissions have large spatiotemporal variability. Therefore, it is always unclear whether the obtained area-specific EF and SF_w exactly reflect the actual values of each rice-growing season. This uncertainty raises the question for the responsible party of whether GHG emissions should be monitored every season or not. Season-by-season monitoring of GHG emissions is also an issue for the verification process, because it is the only way to directly verify the reported emission reduction (see chapter 5). As a compromise, the SF_w can be varied, depending on the reported actual achievement of drainage events. Tirol-Padre et al. (2018) reported that the number of non-flooded days and the minimum water level below the soil surface were the only significant predictors of SF_w for AWD by stepwise selection and multiple regression analysis of data from the loamy soils of Hue, Vietnam and Jakenan, Indonesia. This possibility would be attractive to the responsible party rather than always using the most conservative value a fixed SF_w. Furthermore, a modeling approach may be necessary to take account of the seasonal variations of EF and SF_w (see subchapter 3.7).

3.5. N_2O emissions and CO_2 exchanges

Because it should be possible to use this handbook to develop the most stringent MRV methodology, both N_2O emissions and CO_2 exchanges should be quantified as well as CH_4 emissions (Figure 3.2). If the materiality of the sinks, sources, and reservoirs of each GHG is below the threshold set for a project (e.g., <5% or <10% of the total GWP of the three GHGs), the responsible party can omit them from the calculation of total GHG emissions.

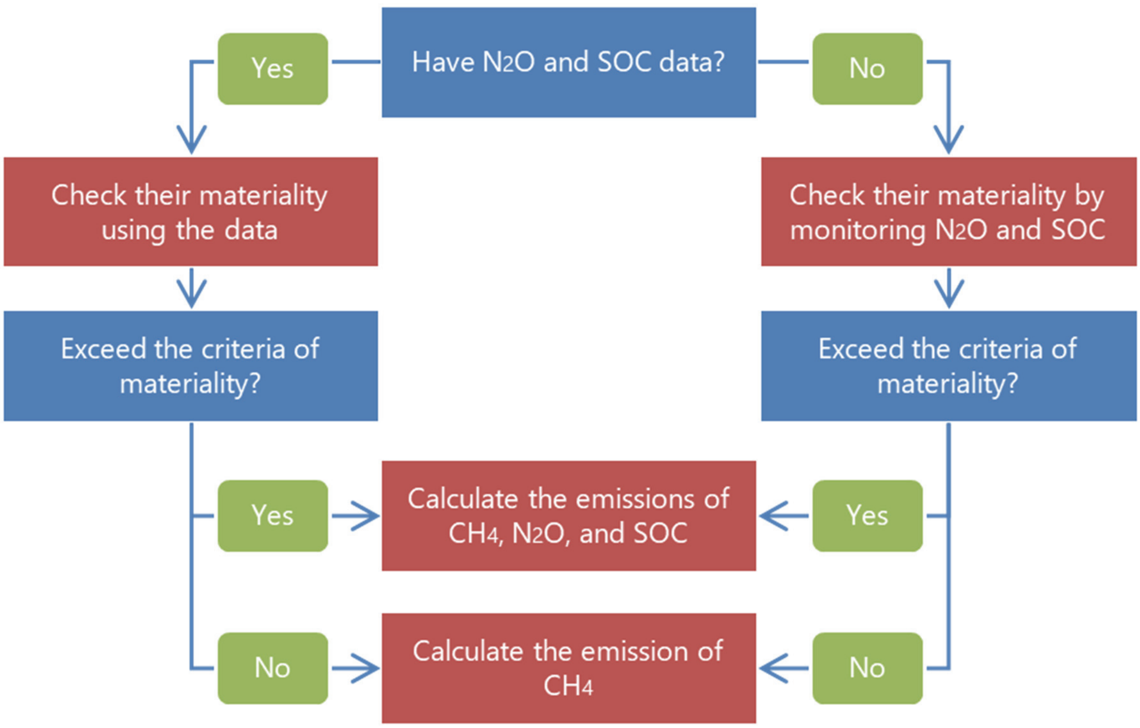

Figure 3.2. Decision tree for the selection of target GHGs among CH_4, N_2O, and CO_2 (SOC).

N_2O emissions from different water management practices can be calculated using the fertilizer-induced EFs and the background emissions from a zero-N plot (Akiyama et al., 2005; Table 3.8 and Equation 3.5) or on-site measurements using the closed-chamber method before project implementation (i.e., area- and management-specific EFs). The IPCC (2006a) has provided only one EF for flooded rice fields of 0.003 kg N_2O-N kg N^{-1} (EF_{1FR}, range of uncertainty: 0.000–0.006) based on the dataset of Akiyama et al. (2005), and thus the responsible party cannot differentiate project from baseline N_2O emissions. Because the spatiotemporal variability in N_2O emission is so high, the responsible party should measure N_2O emissions from fertilized plots and zero-N plots simultaneously with CH_4 emissions using a closed-chamber method. See Minamikawa et al. (2015) for notes on and suggestions for the measurements.

Table 3.8. Fertilizer-induced N_2O emission factor (EF) and background N_2O emissions for different water management practices.

Water management	Fertilizer-induced EF (%)	Background emission (kg N ha^{-1} $season^{-1}$)
Continuous flooding	0.22 (0.24)	0.211 (0.143)
Midseason drainage	0.37 (0.25)	0.372 (0.284)

Modified from Akiyama et al. (2005).

Note: Standard deviation in parentheses.

$$E = [(EF \times R_N) + (N_2O_{background} \times N_{crop})] \times A \times Y \times GWP \quad \textbf{(Equation 3.5)}$$

where E is total emissions (kg CO_2-eq ha^{-1}); EF is fertilizer-induced emission factor (%); R_N is the rate of N fertilizer application (kg N ha^{-1} yr^{-1}); $N_2O_{background}$ is the background N_2O emission (kg N ha^{-1} $season^{-1}$); N_{crop} is number of rice cropping season (yr^{-1}); A is area (ha); Y is the time interval (yr); and GWP is the global warming potential (kg CO_2 kg N_2O-N^{-1}).

As mentioned in subchapter 2.2, temporal changes of SOC can be a proxy for the balance of CO_2 exchanges during the crediting period. Because CO_2 exchange consists of various components, the measurement is complicated compared to measurements of CH_4 and N_2O emissions using the closed-chamber method. Therefore, if SOC data are not available for the project area, the annual/seasonal SOC change should be monitored at least during the crediting period to demonstrate the absence (or presence) of SOC loss. (Figure 3.2; see also subchapter 4.2). See IPCC (2006a) and Echnoserve (2014) for detailed measurement methods.

3.6. Uncertainty of GHG calculation results

Reducing the uncertainty associated with calculated GHG emissions means maximizing the potential for emission reduction (i.e., additionality) based on the principle of conservativeness. The IPCC (2006b) has suggested the following seven general ways to reduce uncertainty: (1) improving conceptualization, (2) improving models, (3) improving representativeness, (4) using more precise measurement methods, (5) collecting more measured data, (6) eliminating known risks of bias, and (7) improving the state of knowledge. These ways should be undertaken by the responsible party. In other words, the width of the range of uncertainty partly reflects the current ability of the responsible party versus the limits to the cost of MRV implementation.

Quantitative uncertainty analysis of GHG emissions is usually performed by estimating the 95% confidence interval (hereafter designated as 95%CI) (IPCC, 2006b). For example, the 95%CI of the CH_4 flux (mg CH_4 m^{-2} h^{-1}) simultaneously measured at ten points in the project area was calculated as follows:

Measured CH_4 flux: 5.10, 5.10. 5.20, 4.90, 5.00, 5.40, 5.30, 5.20, 5.00, and 4.80
Mean (M): 5.10 t value (df = 9, α= 0.05): 2.262 Standard error (SE): 0.06
95%CI = $t_{9,0.05}$ × SE = 0.13
(95%CI expressed as percentage = 95%CI / M × 100 = 2.54%)
➔ CH_4 flux is calculated to be 5.10 ± 0.13 mg CH_4 m^{-2} h^{-1} in this example.

There are two approaches to combining multiple uncertainties associated with parameters that are required to calculate GHG emissions, such as the 95% CI in the gas flux calculation above, the precision in machinery gas concentration analysis, and the errors in statistics. The first approach is to use the error propagation equation; the second approach is to use Monte Carlo or similar techniques (IPCC, 2006b). Here, we introduce the equation for the first approach as follows [see IPCC (2006b) for further detailed information]:

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2} \quad \textbf{(Equation 3.6)}$$

where U_{total} is the combined uncertainty and U_n is the uncertainty of the n^{th} parameter.

We raise three evolving issues about the calculation of uncertainty. The first issue is the variabilities of GHG measurements and agricultural activity, which cannot be quantified. For example, how can the responsible party quantitatively evaluate the skill of gas sampling operators? Although pictures are useful as part of the data to be reported (see subchapter 4.2), the errors associated with manual operation cannot be quantified and hence cannot be directly reflected in the calculated GHG emissions. To address such issues, the IPCC (2006b) proposed that the range of uncertainty be set based on expert judgement.

The second issue is the large uncertainty that exists even after great efforts have been made to reduce it. If the ready-made EF and SF_w of CH_4 are available (see subchapter 3.3), the default EF and SF_w (Table 3.2) of the IPCC may be more attractive in terms of GHG emission reduction. The responsible party may then select the default values instead of the obtained area-specific values. We therefore propose the concept of assuring the minimum effect of project water management, even if wide uncertainty exists and thus violates the principle of conservativeness. For example, in the current version of CDM methodology for paddy water management (UNFCCC, 2014), conservativeness is disregarded for purposes of calculating the potential reduction of CH_4 emissions.

The last issue is the necessity of statistical significance (e.g., $p < 0.05$ for a t-test) for reduction of GHG emissions by project water management. Can the responsible party assure a certain reduction of GHG emissions by project water management without statistical significance? This issue is especially important because GHG measurements with the closed-chamber method can include a limited number of sampling points compared to a non-point source. A lack of statistical significance implies a wide uncertainty that can be reflected in the calculation of the reduction of CH_4 emissions. However, as is apparent in the overlap of errors (standard deviations) between the three IPCC SF_ws (IPCC, 2006a; Table 3.2), statistical significance is often disregarded in the national GHG inventory.

3.7. Possibility of process-based modeling approach

Mathematical modeling of GHG emissions under different water management scenarios is a possible Tier-3 method of calculating GHG emissions. Actually, ACR, a voluntary carbon offset program in the United States, has approved the MRV methodology "Voluntary Emission Reductions in Rice Management Systems" that uses the calibrated and validated DNDC, a process-based biogeochemical model originally developed by Li et al. (1992) as the main quantification tool (ACR, 2013). The California Air Resources Board (2015) has also developed an MRV methodology called "Compliance Offset Protocol Rice Cultivation Projects" that uses DNDC. DNDC-Rice, a revised version of DNDC specific to rice paddies (Fumoto et al., 2008 and 2010) has also been used to simulate GHG emissions from rice paddies under varying water management scenarios in Japan and Thailand (Minamikawa et al., 2014 and 2016). Furthermore, DNDC-Rice has been approved as the main tool for estimating CH_4 emissions from rice cultivation in Japan since 2016, which is submitted to the UNFCCC as the national GHG inventory (GIO, 2016; Katayanagi et al., 2016).

GHG modeling for a rice area generally requires (1) a measured GHG emission dataset for prerequisite model calibration/validation and (2) various area-specific input parameters (e.g., soil, weather, and agricultural activity). However, an advantage of the modeling approach is that multivariable-dependent GHG emissions and their reduction can be estimated, which is impossible using the conventional approach with fixed EF and SF_w values. Another advantage is that the modeling approach can save MRV costs when targeting a wide project area if measured data for model calibration/validation are already available (e.g., the region-specific modules prepared in the ACR methodology).

4. Requirements for monitoring and reporting

4.1. Summary

This chapter introduces the data that must be monitored and reported in a project for paddy water management. Such monitoring and reporting are essential to demonstrate appropriate implementation of project water management.

- ✓ Items that shall be monitored and reported include basic information on agricultural activities, including water management, and rice productivity during the crediting period.
- ✓ Criteria for appropriately implementing project water management shall be determined based on the definition of project water management, the required level of assurance, the spatial scale of the project area, and the limitations imposed by MRV costs.

4.2. Data necessary to assure GHG calculation results

The responsible party shall assure calculated GHG emission reductions by monitoring and reporting the required items. The items and their collection methods may depend on the spatial scale of the project and the required level of assurance in the parent program (e.g., difference between market mechanisms and NAMAs).

Table 4.1 lists the candidate items for monitoring and reporting. Most are quantitative items, except for rice stage and disease. Video and photographs can be used to verify such qualitative items. The logbook of the rice producer, purchase receipts, electronic datasets, and pictures are appropriate materials to be reported. When the project includes soil N_2O as a GHG source, the details of N fertilizer application (type, rate, and timing) shall be monitored and reported. When the project includes soil CO_2 (SOC) as a GHG source/sink/reservoir, the SOC concentration in the topsoil should be monitored and reported at an appropriate frequency. See ACR (2013) and California Air Resources Board (2015) for the input parameters needed for the modeling approach using DNDC.

Table 4.1. Examples of items to be monitored and reported.

Category	Items
Weather	Precipitation, air temperature, extreme events.
Water use	Irrigation volume, pump fuel usage.
Agricultural practices	Event date, fertilizer, agrochemicals.
Water management	Surface water level, dates of irrigation and drainage.
Rice productivity	Growth stage, disease and pests, grain yield.
Soil properties	Moisture conditions, C concentration.

See Minamikawa et al. (2015) for details.

4.3. Appropriate criteria for paddy water management

For a project with paddy water management, precise control of the surface water level, soil moisture conditions, and irrigation volume are necessary to achieve the expected reduction of CH_4 emissions. However, precipitation may disturb planned drainage events. Table 4.2 shows possible criteria for project water management. Basically, the items to be monitored and reported are already determined in the MRV methodology. Surface water level and soil moisture status can be independently used as the sole criterion for a project. The values of these criteria reflect irrigation, precipitation, drainage, and evapotranspiration. However, the number of samples the responsible party should collect depends on the required level of assurance. The combination of irrigation volume and precipitation can allow assessment of the total water input to a unit area (from a field to a project area). As insurance, the responsible party should monitor and report at least two criteria: one from the surface water level or soil moisture status based on the project design, and the other from a combination of irrigation volume and precipitation.

Table 4.2. Candidate criteria for water management and their characteristics.

Criteria	Monitoring method	Advantage/disadvantage
Surface water level	· Automated sensor/logger · Manual reading with gauge	· Direct evidence to demonstrate · Heterogeneity of soil surface level
Irrigation volume	· Water gauge · Estimation from pump fuel/time	· Applicable from field to tract · Need precipitation data
Soil moisture status	· Automated sensor/logger · Manual sampling	· Most scientific evidence · Need scientific background · Heterogeneity of soil surface level
Precipitation	· Nearby weather station · Rain gauge	· Applicable from field to tract · Need irrigation volume data

5. Requirements for validation and verification

5.1. Summary

This final chapter introduces practical tips and near-future expectations for the validation and verification process implemented by a third party. Although the validation and verification process is independent of the monitoring and reporting processes implemented by the responsible party, the methodology for validation and verification should be developed by common consent among all the concerned parties in accord with the six MRV principles.

- ✓ Verifiers and validators should understand the ability and limitations of the currently available techniques to quantify soil GHG emissions with high spatiotemporal variability.
- ✓ In the near future, more comprehensive and innovative methods need to be developed and adopted to reduce MRV costs in the validation and verification process.

5.2. Practical aspects

A third party may serve as both the verifier and validator. Validation and verification shall be implemented before and after the monitoring and reporting processes, respectively (see Figure 1.1). Although the verified results are used as the basis for the insurance of credits, validation is also a cardinal process that assures the credibility of the project design. In other words, the success or failure of a project strongly depends on the validation process.

Needless to say, skill in reviewing reported items is essential for validator and verifier. Because irrigated rice paddies are non-point sources of GHG emissions with high spatiotemporal variability, the validator and verifier should understand the degree of normal spatiotemporal variability of the soil GHG emissions. In addition to the reviewing skill, validator and verifier shall have scientific knowledge of paddy soil biogeochemistry, especially for soil GHG emissions. Outsourced scientific experts may instead play this role. The level of assurance in the validation and verification process differs among parent programs (Bellassen et al., 2015). The validator and verifier should at least understand the highest level of assurance in the context of this handbook.

There are several practical tips for on-site inspection by the validator and verifier. These tips cannot be learned from a paper review alone. The first tip is to be aware of the qualitative nature of manual monitoring (see also subchapter 4.2). Although video/photographs are useful for this purpose, the validator and verifier should have the ability to check the expertise and consistency of monitors. The second tip concerns the spatial representativeness of monitoring points in a field and also in the whole project area. Heterogeneities of soil and agricultural activities strongly affect the magnitude of GHG emissions. The last tip concerns the feasibility of irrigation and drainage (artificial or gravity) around a field/project area (see also subchapter 2.3). Validator and verifier should check the topography and equipment for appropriate irrigation and drainage.

5.3. Scientific aspects

The development of validation and verification techniques is still ongoing. Table 5.1 shows examples of the three techniques currently available. In addition to a regular review of logbook and reported papers, video/photographs are useful to document the ongoing activities (technique 1). Comparison with other independent data can support or demonstrate the reported activities (technique 2), and double checking using these two techniques is consistent with the principle of transparency. On-site direct monitoring during the crediting period, such as chamber GHG sampling and inspection, is the basis for the validation and verification process (technique 3); however, such monitoring costs time and money. Although direct monitoring after the crediting period is a possible technique that has already been introduced in CDM projects, comparison of CH_4 emissions during and after the crediting period makes no sense.

Table 5.1. Outline of three currently available techniques for validation and verification of items monitored and reported.

	Technique 1 Reviewing reported materials	Technique 2 Comparison with other independent datasets	Technique 3 On-site direct monitoring
GHG emissions	· Calculation equations and errors · Auxiliary data · Lack of data · Uncertainty range	· National inventory report · National communication · Published papers	· Chamber monitoring
Area of cultivation	· Calculation errors · Lack of data · Uncertainty range	· Statistics · GIS-derived data · Published papers	· Location survey
Number and length of season	· Logbook · Photos	· Weather conditions · GIS-derived data	· Inspection
Volume of irrigation and drainage	· Logbook (water gauge and pump) · Uncertainty range	· Precipitation data · Data related to irrigation	· Performance of water gauge and pump
Surface water level	· Logbook (water level gauge) · Uncertainty range	· Precipitation data	· Performance of water level gauge · Spatial variability
Straw management	· Logbook · Photos	· GIS-derived data (after harvest)	· Inspection (after harvest)
Fallow season's soil moisture conditions	· Logbook (flooded period) · Photos	· Precipitation data	· Inspection · Automated sensor/logger

Reducing MRV costs in the validation and verification process is a major evolving issue to be addressed in the near future. On-site inspection may be replaced by video/photographs and automated sensors/loggers (see also subchapters 4.2 and 4.3). Even if currently not available, some comprehensive and smart techniques will be established in the near future. Remote sensing has already been available for some aspects of agricultural activity (technique 2). Remote sensing techniques are also expected to be applied to monitor rice growth and surface water level.

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See also "Recommended readings" for references not listed here.

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Authors' affiliations

Lead authors

Kazunori Minamikawa (minakazu@affrc.go.jp)

Institute for Agro-Environmental Sciences, NARO, Tsukuba, Ibaraki, Japan

Takayoshi Yamaguchi (ladakh2008@affrc.go.jp)

Institute for Agro-Environmental Sciences, NARO, Tsukuba, Ibaraki, Japan

Takeshi Tokida (tokida@affrc.go.jp)

Institute for Agro-Environmental Sciences, NARO, Tsukuba, Ibaraki, Japan

Shigeto Sudo (ssudo@affrc.go.jp)

Institute for Agro-Environmental Sciences, NARO, Tsukuba, Ibaraki, Japan

Kazuyuki Yagi (kyagi@affrc.go.jp)

Institute for Agro-Environmental Sciences, NARO, Tsukuba, Ibaraki, Japan

Contributing authors

Agnes Padre (a.padre@irri.org)

International Rice Research Institute, Los Baños, Laguna, Philippines

Dang Hoa Tran (trandanghoa@huaf.edu.vn)

Hue University of Agriculture and Forestry, Hue, Vietnam

Amnat Chidthaisong (amnat_c@jgsee.kmutt.ac.th)

The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok, Thailand

Evangeline B. Sibayan (eb.sibayan@philrice.gov.ph)

Philippine Rice Research Institute, Muñoz, Nueva Ecija, Philippines

Ali Pramono (ali_pramono@yahoo.com)

Indonesian Agricultural Environment Research Institute, Pati, Central Java, Indonesia

Miho Mochizuki (mihosuke@affrc.go.jp)

Institute for Agro-Environmental Sciences, NARO, Tsukuba, Ibaraki, Japan