Greenhouse Gas Mitigation by Alternate Wetting and Drying Water Management in Irrigated Rice Paddies in Southeast Asia

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1. Introduction to MIRSA-2 project

Rice is a dominant staple food mostly produced in Asia. Rice cultivation is recognized as a major anthropogenic source of the atmospheric CH_4 abundance. The latest IPCC assessment report estimates that rice cultivation account for ~11% of the total anthropogenic CH_4 emission (Ciais *et al*., 2014). Especially in rice-producing Asian countries, CH_4 emission from rice paddies contributes substantially to the national greenhouse gas (GHG) inventory.

Paddy CH_4 emission can be mitigated by altering the soil environment surrounding the production, consumption, and emission processes. Water management in irrigated paddies and organic matter management are the top two options because CH_4 is produced from organic carbon by microbes under strictly reductive soil conditions. AWD is the water saving technique originally developed and being extended by the International Rice Research Institute, and also known as effective in mitigating paddy CH_4 emission. However, there is limited information so far on the local feasibility of AWD in terms of GHG emission, water saving, and rice productivity.

MIRSA-2 is the ongoing five-year (FY2013-2017) international research project funded by the Secretariat of the Agriculture, Forestry and Fisheries Research Council of the Ministry of Agriculture, Forestry and Fisheries of Japan, in order to support the goals of the GRA Paddy Rice Research Group. MIRSA-2's research objective is to develop improved water management based on AWD that can always reduce CH_4+N_2O emission from irrigated rice paddies in Asian countries. This paper introduces the current progress of MIRSA-2.

2. Field demonstration of AWD feasibility in Southeast Asian countries

A three-year field experiment was conducted at four sites: Hue, Vietnam; Prachin Buri, Thailand; Muñoz, Philippines; and Jakenan, Indonesia, to assess the site-specific feasibility of AWD. The experiment covered wet season (WS) rice as well as dry season (DS) rice with shared experimental settings and methods, and compared three water management practices: continuous flooding (CF) and two types of AWD (i.e., safe-AWD and site-specific AWD).

The seasonal CH_4 emission under CF varied substantially from 13.4 kg CH_4 ha^{-1} in Prachin Buri DS to 644.2 kg CH_4 ha^{-1} in Hue WS as affected by weather conditions and soil properties. The seasonal CH_4 mitigation potential of AWD relative to CF ranged from 16% to 43% excluding Muñoz WS where drainage was impossible due to heavy rainfall. The variance-weighted mean CH_4 mitigation potential of AWD was 31% with bootstrapped 95% confidence interval of 23-39% across sites and seasons excluding Muñoz WS. This value was slightly lower than the IPCC's default scaling factor for multiple aeration of 48% with error range of 34-59% (IPCC, 2006).

There was no significant ($p < 0.05$) effect of water management on the seasonal N_2O emission, but an emission increase under AWD was observed in Muñoz, Jakenan, and Prachin Buri. The mean emission factors under CF and AWD across sites and seasons were 0.23 ± 0.17% and 0.13 ± 0.18% (mean ± 95% CI), respectively. These were comparable to those reported by Akiyama *et al*. (2005) of 0.22 ± 0.12% under CF and 0.37 ± 0.20% under midseason drainage (mean ± 95% CI).

There was significant effect of water management on CO_2-equivalent emission of CH_4+N_2O calculated using the latest IPCC's Global Warming Potential. The total carbon and nitrogen contents in 0-20 cm soil layer did not significantly differ among three water management practices on each annual/seasonal sampling date at every site. Furthermore, AWD showed no significant reduction in rice grain yield. Total water use (i.e., irrigation + rainfall) was significantly reduced by AWD.

In Prachin Buri and Muñoz, AWD was unsuitable during WS due to the frequent rainfall and the slow water percolation in clayey soils. On the other hand, AWD was effective even during WS in Hue and Jakenan, both of which had a loamy soil. The field experiment underscores the importance of practical feasibility and appropriate timing of water management in successful GHG mitigation by AWD.

3. Development of MRV guidelines for paddy water management

The development of mitigation options in rice cultivation has been advancing, but the spread to rice producers or the social implementation is limited so far. Rice producers can gain economic incentive through participating in a GHG mitigation project driven by carbon pricing, such as carbon tax and market mechanisms. However, MRV methodology required to implement such projects has not been well documented.

MRV is a system in which the three processes are integrated to ensure the accuracy of GHG emissions and reductions from a certain project compared to the baseline practice. Recently, market mechanisms (i.e., internationally transferred mitigation outcomes, ITMOs) is articulated under the Paris Agreement (UNFCCC, 2015), which prescribes for the use of emission reductions realized oversees towards national emission reduction targets. This will accelerate the institutional spread of mitigation options in agricultural sector including rice cultivation.

MIRSA-2 is now developing the introductory book for developing MRV methodology of water management in irrigated rice paddies with reference to CDM’s methodology of paddy water management (UNFCCC, 2014), etc. As preliminary steps toward the introductory book, MIRSA-2 has developed the guidelines for measuring paddy GHG emission by a closed chamber method through integrating knowledge and experience (Minamikawa *et al*., 2015). This will be useful for the person/party concerned in MRV as well as field researchers.

In addition, to understand the spread process of paddy water management (AWD) to rice producers, MIRSA-2 conducted a series of social surveys in An Giang province, Mekong Delta, Vietnam (Yamaguchi *et al*., 2016; in press). The surveys found that (i) local farmers have modified the manner of AWD to meet their own objectives and (ii) co-benefits from AWD, such as decreases in rice lodging and damage, are a key in voluntarily spreading the technology. The information obtained are to be incorporated to the introductory book as the factors in affecting the feasibility of paddy water management.

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