EFFORTS OF NATIONAL INSTITUTE FOR AGRO-ENVIRONMENTAL SCIENCES/NATIONAL AGRICULTURE AND FOOD RESEARCH ORGANIZATION IN APPLYING GREENHOUSE GAS MITIGATION TECHNOLOGIES TO MONSOON ASIAN COUNTRIES AND INTERNATIONAL FRAMEWORKS SINCE 2011

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ABSTRACT

Over the past number of years, the National Institute for Agro-Environmental Sciences (NIAES), which was integrated into the National Agriculture and Food Research Organization (NARO) in April 2016 to form NIAES/NARO, has examined the widespread application of climate change mitigation technologies to many monsoon Asian countries. To encourage the dissemination of these technologies, NIAES/NARO has also formulated guidelines and a handbook. In addition, NIAES/NARO has made positive contributions through its involvement in many international frameworks, such as the Global Research Alliance on Agricultural Greenhouse Gases, Intergovernmental Panel on Climate Change, and The 4 per 1000 Initiative. In these endeavors, NIAES/NARO has achieved success with respect to the specific contents of individual research fields, moving toward a direction of generalization of obtained results. In the next step, to increase the applicability of research results to the society, should NARO consider site-specific efforts more, thus incorporating the evaluation indicators of broader research fields and multiple stakeholders?

Keywords: NIAES, NARO, GHG mitigation technology, China, India, Indonesia, Philippines, Thailand, Vietnam, GRA, IPCC, the 4 per 1000 Initiative

INTRODUCTION

Efforts to mitigate cross-border climate change have a limited effect when only local/domestic measures are applied. Therefore, it is important to consider the regional application of climate change mitigation technologies and to encourage their dissemination within the region. Based on this idea, by targeting monsoon Asian countries, where rice is an important agricultural crop as in Japan, NIAES/NARO has been trying to apply developed technologies to reduce greenhouse gas (GHG) emissions from agricultural lands, particularly rice paddies. In addition, NIAES/NARO has been aiming to create guidelines and handbooks to help disseminate these technologies and to actively contribute to international efforts through its involvement in international frameworks. This review highlights some of the major achievements of NIAES/NARO in the aforementioned fields since 2011 and also reviews its activities to consider future directions for research and practical applications.

APPLICATION OF GHG EMISSION-REDUCTION TECHNOLOGIES TO MONSOON ASIAN FARMLANDS AND EVALUATION OF THEIR IMPACT

NIAES/NARO has been applying GHG emission-reduction technologies in many monsoon Asian countries to demonstrate the applicability of these technologies. The following are some of the major achievements of NIAES/NARO in these countries since 2011.

A multi-country on-site demonstration of GHG emission-reduction effect by introducing a water-saving irrigation technology (AWD) in irrigated paddy fields in Vietnam, Thailand, the Philippines, and Indonesia

Field experiments were performed in cooperation with the International Rice Research Institute, the Philippines; University of Agriculture and Forestry, Hue University, Vietnam; the Joint Graduate School of Energy and Environment, King Mongkut's University of Technology, Thonburi, Thailand; the Philippine Rice Research Institute; and the Indonesian Agricultural Environment Research Institute, in a research project financially supported by the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF; FYs 2013–2017). The GHG emission-reduction effects of an intermittent-irrigation technology, called "alternate wetting and drying" (AWD) that has been disseminated across rice-producing countries, mainly Asia, were demonstrated. Under AWD irrigation control, irrigation water is not applied until the soil moisture decreases to a certain level (e.g., until the field water level drops to 15 cm below the soil surface) after the standing water has been disappeared, except during some specific periods. As aeration of the shallow soil is normally performed multiple times during the cropping period under this irrigation control strategy, the application of the AWD irrigation method is believed to contribute to the reduction in methane (CH_4) emissions generated under anaerobic conditions. However, the quantitative effects of this strategy under diverse Asian rice paddy environments had not been fully elucidated till date. Therefore, field trials were conducted at four sites in Southeast Asia (Hue, Vietnam; Prachinburi, Thailand; Muñoz, the Philippines; and Jakenan, Indonesia) for 3 years to evaluate the effects of introducing AWD to irrigated rice paddies (each with two cropping seasons, i.e., the dry and rainy seasons), using GHG emissions, rice productivity, and water use as indicators. In the experiments, the following two types of AWD treatments were compared with the conventional continuous flooding (CF) treatment. All treatments involved no artificial draining except just before harvesting.

- Safe AWD: In this technique, irrigation is performed only when the field water level drops to 15 cm below the soil surface, except during some specific periods (saturated just after sowing, flooded during the heading period in some cropping seasons at certain experimental sites, and/or flooded at topdressing in most cropping seasons).
- Site-specific AWD: This is a modification of the safe AWD according to the recommendations of the researchers in charge of each field trial.

The results indicated that, although CH_4 emissions significantly differed between the target sites because of differences in soil characteristics and fertilizer management between sites, the volume of CH_4 emissions was reduced by AWD (considering both Safe AWD and Site-specific AWD, collectively referred to "AWD" in the rest of this paragraph) at all times compared with CF, except for the wet season in the Philippines; because the area around the experimental site in the Philippines was continuously flooded throughout the wet season, no difference in field water management was made between AWD and CF. The average reduction in GHG emission, excluding that observed during the wet season in the Philippines, was 31%. The yield of the representative rice variety of each target site did not significantly decrease in any cropping season because of the application of AWD, and the volume of water used (including both irrigation water and precipitation) was 6%–47% (for the dry season) and 6%–17% (for the wet season) lower for AWD compared with those for CF (Chidthaisong *et al*., 2018; Setyanto *et al*., 2018; Sibayan *et al*., 2018; Tirol-Padre *et al*., 2018; and Tran *et al*., 2018).

On-site verification of the effect of the System of Rice Intensification (SRI) in a South Asian irrigated paddy field

This research was financially supported by the Ministry of the Environment, Japan.

SRI is a methodology that aims to increase the yield of rice by minimizing anaerobic soil conditions and by using younger seedlings singly that are optimally and widely spaced. SRI was first developed in the 1980s by Fr. Henri de Laulanié S.J. in Madagascar (Laulanié *et al.* 2011) and has been tested and disseminated with the help of scientists such as those from the Cornell University; however, the effectiveness of SRI has been under debate between supporters and critics of the system. To reach a consensus, the effects of introducing SRI were evaluated in Tamil Nadu, South India, wherein SRI has been already been used, by employing rice productivity, water use, and GHG emissions as indicators.

A significant yield increase effect achieved by SRI, which SRI supporters had argued as the main benefit of SRI introduction, was not observed. On the contrary, water use was reduced by 48%–49% (dry season) to 79%–80% (wet season), and GHG emissions (total CO_2-equivalents of CH_4 and N_2O emissions) were reduced by 41%–48% (dry season) to 24%–26% (wet season) with the introduction of rice-cropping technologies combined with widely spaced transplanting of young seedlings and/or AWD water-saving irrigation (Oo *et al*., 2018).

On-site demonstration of the effect on annual GHG emissions of introducing dry-season cropping to a rainfed rice field in Thailand

In the rainfed rice paddies of Thailand, usually no crop is cultivated during the dry season. During a five-year field experiment, the effect on CH_4 and N_2O emissions and on soil carbon stocks following the introduction of dry-season cropping to a rainfed rice field in Thailand was evaluated. The results indicated that GHGs equivalent to 38 t CO_2 ha^{-1} y^{-1} (total CO_2-equivalents of CH_4 and N_2O emissions and soil carbon reduction, as used for the rest of this paragraph) were annualy emitted when irrigated rice cropping was introduced in the dry season. On the contrary, when maize/sorghum cropping was introduced in the dry season, annual GHG emissions reduced to approximately one-quarter of that achieved by introducing irrigated rice cropping in the dry season. Analyzing GHG emissions showed that CH_4 emissions from maize/sorghum cropping compared with those from rice cropping were significantly lower; however, there was no significant impact of maize/sorghum cropping on soil carbon content (Cha-un *et al.*, 2017).

CREATION OF GUIDELINES AND A HANDBOOK FOR TECHNOLOGY DISSEMINATION

As described above, NIAES/NARO has been applying GHG emission-reduction technologies to many monsoon Asian countries to demonstrate the applications of these technologies. "Know-how" gained through the demonstration activities needed to be summarized in a form that anyone can use. "Guidelines for measuring CH_4 and N_2O emissions from rice paddies with a manually operated closed chamber method" and "Handbook of monitoring, reporting, and verification for a greenhouse gas mitigation project with water management in irrigated rice paddies" were published in 2015 and 2018, respectively.

"Guidelines for measuring CH_4 and N_2O emissions from rice paddies with a manually operated closed chamber method"

As with the multi-country on-site demonstrations described above, these guidelines (Minamikawa *et al.*, 2015) are a product of the research project supported financially by MAFF (FYs 2013–2017). A manually operated gas sampling chamber is commonly used to monitor GHG fluxes from paddy fields. Several manuals on this method had been published in the 1990s, following which little noticeable publicity was observed. On the other hand, each researcher/research group established their own measurement methods empirically in respect to their particular local field conditions, as described in Minamikawa *et al.* (2015). Therefore, guidelines suitable to different rice-cropping areas were created. The guidelines had the following features:

- The guidelines were developed based on requests from the Paddy Rice Research Group of the Global Research Alliance on Agricultural Greenhouse Gases (GRA), an international research network based on intergovernmental agreement. The guidelines were approved at the Asia Sub-group meeting held in September 2015, and could be viewed and downloaded for free from the GRA website (Minamikawa *et al.*, 2015).
- The guidelines are not rigidly applied uniform measurement methods based on the most advanced technologies but were prepared assuming

that measurements could and should be adapted to the circumstances and conditions of each particular site (regardless of the procurement status of experimental materials, tools, equipment, or the like).

- The document comprises a summary of “recommendations” and “evolving issues” as well as seven chapters. Chapters 2 to 7 cover topics ranging from “experimental design” at the preparation stage to “data processing” after completion of the measurements.
- Advice, gleaned from years of experience of measuring GHG emissions in Japan, is included in the document, aimed at improving the skills of the technicians.
- The guidelines facilitate the estimation of the GHG emissions from paddy fields with the necessary accuracy to develop and quantitatively evaluate measures for the reduction of emissions.

“Handbook of monitoring, reporting, and verification for a greenhouse gas mitigation project with water management in irrigated rice paddies”

As with the guidelines, this handbook (Minamikawa *et al.*, 2018) is a product of the GRA research project supported financially by MAFF (FYs 2013–2017). Social implementation (by dissemination to producers) of global warming mitigation measures in the agricultural sector has not progressed satisfactorily and further promotion is required to achieve substantial GHG emission reductions. The Paris Agreement, which came into effect in 2016, proposes the use of institutional emission-reduction plans in developing countries, such as emissions trading and nationally appropriate mitigation actions. In Asian rice-producing countries, in particular, CH_4 emissions from paddy fields account for a significant proportion of the anthropogenic GHG emissions, and the expectations for an institutional emission-reduction plan are therefore considerable. However, the methodology for “monitoring, reporting, and verification (MRV),” which is essential for institutional implementation, has not been established sufficiently in the agricultural sector, unlike the situation in the industrial sector. Consequently, an English language MRV handbook, that can be used to institutionally implement a project for CH_4 emission reduction via water management in irrigated rice paddies, was prepared, and has been available on the NARO and GRA websites (Minamikawa *et al.*, 2018).

The handbook has the following features:

- Scientific and quantitative descriptions are emphasized, assuming emissions trading and the like that require the rigorous institutional design of MRV methodology, and problems on the current situation in the institutional design development are described.

- In addition to the global warming mitigation effect, an advantage for producers is a shortcut to implementation and dissemination of mitigation measures. In the introduction, the practical mitigation measures to achieve social implementation are categorized into three types (voluntary, semi-institutional, and institutional), their respective characteristics are described, and the importance of an institutional approach from the viewpoint of the amount of emission reduction achieved is indicated.
- Paddy fields are non-point sources of CH_4, and the emissions fluctuate significantly with respect to time and space. In Chapter 3, it is clearly stated that the rate of CH_4 emission reduction by appropriate water management strategies needs to be calculated conservatively taking into account various uncertainties.
- The costs for implementing MRV need to be reduced in future, taking into consideration a balance between cost and the accuracy of the calculations. In Chapter 3, in addition to the calculation method using the emission factor based on measurements taken at the site, a calculation method using mathematical models is introduced. This calculation has received attention in recent years.

CONTRIBUTION THROUGH INTERNATIONAL FRAMEWORKS

In addition to above-mentioned activities, NIAES/NARO has also been contributing actively to international efforts through international frameworks, such as Global Research Alliance on Agricultural Greenhouse Gases (GRA), Intergovernmental Panel on Climate Change (IPCC), and “The 4 per 1000 Initiative,” as follows.

Contribution through Global Research Alliance (GRA) on agricultural greenhouse gases

GRA is an initiative to strengthen the ties among people and countries faced with agricultural GHG challenges. At a side event of the 15th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 15), held in Copenhagen in December 2009, the establishment of GRA was declared jointly by 21 countries including Japan, and in June 2011 at the GRA Ministerial Summit in Rome, the GRA was launched formally by the signing of its charter by 32 countries (the number of member countries as of February 2019 had increased to 56). NIAES/NARO has been intensely involved in GRA activities together with MAFF from before its official launch, such as by leading the activities of GRA’s Paddy Rice Research

Group (PRRG) and acting as Chairperson of the group (co-chaired with Uruguay since June 2011). Staff members of NIAES/NARO have contributed to the activities of PRRG by attending and hosting various meetings, including the following official meetings as Chairperson/Co-Chairperson of PRRG, etc.:

Feb 2010	(Tokyo, Japan) A meeting at MAFF when Mr. Groser, NZ Trade Minister, visited MAFF to request Japan to join GRA
Apr 2010	(Wellington, NZ) A meeting to launch GRA
Sep 2010	(Tsukuba, Japan) MARCO/GRA Joint Workshop on Paddy Field Management and Greenhouse Gases
Mar 2011	(Versailles, France) The 2nd high-level official meeting/PRRG Meeting
Jun 2011	(Rome, Italy) GRA Minister Summit/Council Meeting
Nov 2011	(Tsukuba, Japan) PRRG Meeting
Jun 2012	(Saskatoon, Canada) Council Meeting
Jun 2013	(Montevideo, Uruguay) Council Meeting/PRRG International Workshop
Oct 2013	(Bogor, Indonesia) PRRG Meeting
May 2014	(Cali, Colombia) PRRG Meeting
Jun 2014	(The Hague, Netherlands) Council Meeting
Aug 2014	(Los Baños, Philippines) PRRG Meeting
Mar 2015	(Pelotas, Brazil) PRRG Americas Sub-Group Meeting
Sep 2015	(Nanjing, China) PRRG Asia Sub-Group Meeting
Nov 2015	(Des Moines, USA) Council Meeting
Jul 2016	(Stuttgart, USA) PRRG Americas Sub-Group Meeting
Oct 2016	(Mexico City, Mexico) Council Meeting
Aug 2017	(Tsukuba, Japan) Council Meeting/JIRCAS-NARO International Symposium "Agricultural Greenhouse Gas Mitigation"
Sep 2017	(Tsukuba, Japan) PRRG Asia Sub-Group Meeting
May 2018	(Piura, Peru) PRRG Americas Sub-Group Meeting
Sep 2018	(Berlin, Germany) Council Meeting
Oct 2018	(Bangkok, Thailand) Workshop "Rice landscapes and climate change –options for mitigation in rice-based agroecosystems and the scaling-up of climate-smart rice cultivation technologies in Asia"/ PRRG Asia Sub-Group Meeting
Nov 2018	(Parral, Chile) Capacity Building on Management Technologies for Climate-Smart Rice Cultivation in the South-East Asian and Latin American Rice Sector

In addition, one of the objectives of the MAFF-funded research project mentioned above was to support GRA activities. The project, implemented together with the researchers of the GRA-PRRG participating countries, is well recognized by stakeholders as one of the main activities of the GRA.

Other than PRRG, there are currently three research groups (Croplands, Livestock, and Integrative Research Groups [CRG, LRG, and IRG, respectively]) in GRA, and NIAES/NARO has been registered as the national contact institution of Japan for all the research groups, except LRG. In CRG, staff members of NIAES/NARO have been contributing to the activities of the Managing Agricultural Greenhouse Gases Network (MAGGnet), which is one of the main activities of CRG utilizing the GRA network. MAGGnet is an attempt to compile metadata from field experimental sites worldwide where GHG fluxes and soil carbon dynamics are monitored, and to share the data widely. Since 2012, MAGGnet has compiled more than 337 metadata from field experimental sites in 23 countries, including 19 sites in Japan (Liebig *et al.*, 2016). In addition, staff members of NIAES/NARO have attended meetings and contributed to the activities of research groups other than PRRG, such as attending the following meetings:

Nov 2010	(Long Beach, USA) CRG Meeting
Jul 2011	(Leuven, Belgium) Cross-cutting activity (current IRG) C-N Cycles Workshop
Oct 2011	(San Antonio, USA) CRG Meeting
Jul 2012	(Bari, Italy) CRG and C-N Cross-cutting Working Group (current IRG) Joint Meeting
Nov 2013	(Tampa, USA) CRG Meeting
Mar 2014	(Paris, France) C-N Cross-cutting Working Group (current IRG) Workshop “Experimental databases and model of N_2O emissions by croplands: Do we have what is needed to explore mitigation options?”
Jun 2014	(Wageningen, Netherland) Cross-cutting (current IRG) activity C-N Cycles Workshop
Aug 2014	(Debrecen, Hungary) CRG Meeting
Jul 2015	(Brasilia, Brazil) CRG, Inventory (current IRG), and Monitoring Cross-Cutting Group (current IRG) Joint Meeting
Nov 2016	(Phoenix, USA) CRG Meeting
Jan 2018	(Paris, France) IRG Meeting

Contribution to the creation of IPCC guidelines for greenhouse gas inventories

In compiling the "2013 IPCC Wetland Supplemental Guidelines" (Wickland *et al.*, 2014), one of the NIAES staff members has contributed as a Lead Author, including attendance at the following Lead Author Meetings (LAMs):

Nov 2011	(Hayama, Japan) 1st LAM
Feb 2012	(Victoria Falls, Zimbabwe) 2nd LAM
Jul 2012	(Dublin, Ireland) 3rd LAM
May 2013	(Manaus, Brazil) 4th LAM

At the time of preparing "2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol" (IPCC, 2014), one of the NIAES staff members has contributed as a review editor, including attendance at the following meetings:

Mar 2013	(Oslo, Norway) 3rd LAM
Jul 2013	(Chiang-Mai, Thailand) 4th LAM
Oct 2013	(Batumi, Georgia) Thirty-Seventh Session of the IPCC (IPCC-37) and the Meeting of Coordinating Lead Authors and Review Editors for the "2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol" preparation for discussion at the IPCC-37.

Two lead authors from NARO have participated in the "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories". They have been contributing, e.g., by attending the LAMs listed below:

Jun 2017	(Bilbao, Spain) 1st LAM
Sep 2017	(Victoria Falls, Zimbabwe) 2nd LAM
Apr 2018	(Cairns, Australia) 3rd LAM
Oct 2018	(Rome, Italy) 4th LAM

Contribution through "The 4 per 1000 Initiative"

At the "The 4 per 1000 Initiative" established at the initiative of France at COP 21 (Paris) at the end of 2015, one of the NARO staff members has been participating as one of the 14 members of the Scientific and Technical Committee (STC) that provides scientific advice. The initiative was launched with the slogan that, if 0.4% of soil carbon could be increased every year, it would stop the rise of the atmospheric CO_2 concentration. This staff member has been contributing, e.g., by attending and hosting the following meetings:

Nov 2016	(Marrakech, Morocco) 1st Consortium of Members Meeting (CMM)/1st Forum of Partners Meeting (FPM)/1st Meeting of STC (STCM)
Feb 2017	(Tsukuba, Japan) NARO-MARCO International Symposium "Soil Carbon Sequestration: Needs and prospects under the 4 per 1000 initiative"
Mar 2017	(Rome, Italy) 2nd STCM
Jun 2017	(Montpellier, France) 2nd CMM/3rd STCM
Nov 2017	(Bonn, Germany) 3rd CMM/2nd FPM/4th STCM
Jun 2018	(Madrid, Spain) 5th STCM
Dec 2018	(Katowice, Poland) 4th CMM/3rd FPM/6th STCM

In association, the Asian Long-Term Experiment Network for Agriculture was launched and its homepage (http://www.naro.affrc.go.jp/english/laboratory/niaes/altena/index.html) was created.

CONCLUSION

In all the endeavors mentioned above, NIAES/NARO has achieved success. Such efforts should be continued into the future. On the other hand, it should be considered whether the effort may have been biased toward the specific contents of certain research fields and whether the research results may have been biased somewhat toward a direction of generalization of obtained results. As science is rule-based, and systematic knowledge in the first place has been revealed by empirical procedures, such as observation and experimentation, it is natural and necessary for NARO to be ever-conscious of the generalization of outcomes. However, particularly with respect to project research carried out on-site, it might be necessary to be more conscious of practical application trials and the social relevance aimed at developing site-specific technologies for the trial sites, utilizing the results and networks obtained so far. In order to carry this out efficiently, site-specific preliminary work will be important, such as selecting a target that can be expected to have widespread application and significant social influence if successful at that site. For that purpose, participation by experts in wider fields and consideration of the opinions of various stakeholders will become important.

Although the above are considerations for the future, a new research project commissioned by MAFF, which was launched in late November 2018, could be a good starting point for consideration. Under this research project, rice cultivation techniques (including organic matter usage and variety selection) for monsoon Asia that could realize the long-term maintenance of the soil carbon and nitrogen contents and the present yield status while reducing by 30% the total CH_4 and N_2O emissions (converted into CO_2-equivalents) will be developed. This will be achieved through (1) evaluation of GHG emission-reduction technologies based on field observations, (2) evaluation of soil carbon and nitrogen storage and their dynamics, and (3) long-term estimation of GHG emission-reduction effects, using mathematical models.

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