MARCO/GRA Joint Workshop on
Paddy Field Management and Greenhouse Gases

September 1-3, 2010
Tsukuba, Japan

September 1, Wednesday
- Scientific symposium for oral presentations of research
  Venue: *Epochal Tsukuba (Tsukuba International Congress Hall), Room 200*

September 2, Thursday
- Meeting of GRA paddy field management research group
  Venue: *Epochal Tsukuba (Tsukuba International Congress Hall), Room 201B*

September 3, Friday
- One day Excursion

Jointly organized by:

National Institute for Agro-Environmental Sciences (NIAES)
and
Global Research Alliance on Agricultural Greenhouse Gases (GRA)

Supported by:

Agriculture, Forestry and Fisheries Research Council Secretariat,
Ministry of Agriculture, Forestry and Fisheries (AFFRC-MAFF)
and
Japan International Research Center for Agricultural Sciences (JIRCAS)

Rationale:

Paddy fields are recognized as an important source of atmospheric greenhouse gases (GHGs) mainly through the emissions of methane (CH_4) which is specific to flooded ecosystems. Globally, over the last 70 years there has been a rapid increase in the harvest area of rice to meet increasing demand for rice which has resulted in increased emissions of CH_4. In addition, it is suggested that by introducing high-yielding varieties, together with new cultivation technologies, it has brought about an additional increase in CH_4 emissions because of accelerating carbon turnover in the rice-soil system, caused by adding more organic matter to the soil in the form of crop residues. The rate of global CH_4 emissions from rice fields is also expected to increase further in the next decade in order to meet expected consumption rates.

Reducing CH_4 emissions from paddy fields is very important to stabilize atmospheric concentration of the greenhouse gas, which can contribute significantly to mitigate global warming. Because of the possibility of controlling the emissions by agronomic practices, paddy field management must be one of the most likely means of mitigating CH_4 emissions. Actually, it is demonstrated that a number of traditional or improved management practices can mitigate CH_4 emissions, providing a “win-win” outcome rather than a conflict between different economic, environmental and social goals. Those studies also suggested that some mitigation options for CH_4 may promote an increase in the emissions of nitrous oxide (N_2O) or a curb of soil carbon sequestration. Therefore, it is necessary to consider those trade-offs with the fluxes of other GHGs.

Over the last three decades, scientific knowledge for paddy field management and GHG emissions has been accumulated from a series of process studies, field monitoring, and modeling approaches. Major promising options to mitigate GHG emissions from paddy fields, such as improved management of water and rice straw, are proposed. However, there is still a need to improve knowledge sharing of the mitigation options among researchers and policy makers in different regions of the world. Because the systems of rice cultivation are widely diverse depending on climate, social and economical conditions, the options often need to be developed in accordance with those regional conditions. Also, implementation strategies to extend the options successfully to local farmers and communities are needed.

This workshop will provide an opportunity to bring researchers and policy makers from different countries together to exchange the latest information on paddy field management and GHG emissions. The workshop will be jointly supported by the Monsoon Asia Agro-Environmental Research Consortium (MARCO) and the Global Research Alliance on Agricultural Greenhouse Gases (GRA).

Objectives:

This workshop will address:

(1) Overview of the issues related to paddy field management and GHG emissions in monsoon Asian countries and the world,
(2) Monitoring and measurements of GHG emissions from paddy fields,
(3) Mitigation options for GHG emissions from paddy fields,
(4) Compilation and analysis of databases for GHG emissions from paddy fields, and
(5) Modeling GHG emissions from paddy fields.

This workshop aims;

(1) To summarize the stock-take of research activities in each country,
(2) To identify gaps in knowledge at each country, and
(3) To discuss future research needs and possible forms of cooperation.

Official Language:

The official language of the Workshop will be English. However, voluntary services of simultaneous translation for any monsoon Asian languages are welcome, in particular during the discussion sessions.

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1-3 September 2010, Tsukuba, Japan

PROGRAM

Wednesday, September 1 *at Epochal Tsukuba, Room 200*

Scientific Symposium for Oral Presentations of Research

09:00 *Participant Registration*

Opening Session *Chair: K. Yagi and J. Sindo*

09:30 Opening address
Yohei Sato
President, National Institute for Agro-Environmental Sciences

Welcome address
Michiko Matsuda
Deputy Director General, Agriculture, Forestry and Fisheries Research Council Secretariat, Ministry of Agriculture, Forestry and Fisheries

09:50 Outline of the Workshop
Kazuyuki Yagi
National Institute for Agro-Environmental Sciences

Keynote Lectures *Chair: K. Yagi and J. Sindo*

10:00 The Global Research Alliance: Enhancing agricultural greenhouse gas mitigation research across the world
Meredith Stokdijk
Secretariat of the GRA,
Ministry of Agriculture and Forestry, New Zealand

10:30 Climate change research activities at the International Rice Research Institute
Reiner Wassmann
International Rice Research Institute, the Philippines

11:00 Possible options to mitigate greenhouse gas emissions from paddy fields
Kazuyuki Inubushi
Chiba University, Japan

Reports from Rice Producing Countries *Chair: K. Yagi and J. Sindo*

11:30 Integrated greenhouse gas emissions from paddy fields in China
Xiaoyuan Yan
Institute of Soil Science, Chinese Academy of Sciences, China

11:50 Greenhouse gas emissions from Indian paddy fields
Chhemendra Sharma
National Physical Laboratory, India

12:10 *Group Photo and Lunch*

Chairs: C. Sharma and Y. Shirato

13:30 Greenhouse gas emission under different crop management practices in Indonesia
Prihasto Setyanto, Helena Lina Susilawati, Rina Kartikawati, Miranti Ariani, and Titi Sopiawati
Indonesian Center for Agricultural Land Resources Research and Development, Indonesia

13:50 Overview of Research Activity toward Gas Emission in Paddy Rice Production in Vietnam
Nguyen Hong Son and Vu Thang
Institute for Agriculture Environment, Vietnam

14:10 Greenhouse gas emission, mitigation and soil carbon sequestration potential for Thailand paddy fields
Amnat Chidthaisong and Sirintornthep Towprayoon
The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Thailand

14:30 Rice situation, PalayCheck system, and methane emissions in the Philippines
Eduardo Jimmy Pua Quilang, Flordeliza H. Bordey, Rolando T. Cruz, Constancio A. Asis Jr. and Elmer D. Alosnos
Philippine Rice Research Institute, the Philippines

14:50 Rice production practices in Malaysia in relation to GHG emissions
Shuhaimen Bin Ismail
Malaysian Agriculture Research and Development Institute, Malaysia

15:10 *Coffee Break*

Chair: X. Yan and H. Akiyama

15:30 Methane and nitrous oxide emissions from an Uruguayan rice fields
S. Tarlera, V. Pereyra, A. Fernández, J. Terra and Pilar Irisarri
University of the Republic, Uruguay

15:50 Interaction of methane and nitrous oxide emissions from a paddy field with AWD water-saving irrigation management
Yasukazu Hosen
Japan International Research Center for Agricultural Sciences, Japan

16:10 Reducing CH_4 emission from rice paddy fields by altering water management
Shigeto Sudo, Masayuki Itoh and Kazuyuki Yagi
National Institute for Agro-Environmental Sciences, Japan

16:30 Tier 3 estimation of methane emissions from rice fields
Tamon Fumoto, Michiko Hayano and Kazuyuki Yagi
National Institute for Agro-Environmental Sciences, Japan

16:50 *Closing remark*

18:00 ***Workshop Reception*** ***at Epochal Tsukuba, Restaurant ESPOIR***

Paddy Rice Research Group Meeting

2 September 2010

Tsukuba International Congress Center, Tsukuba, Japan

AGENDA

Venue: Room 201B, Tsukuba International Congress Center

Time	Session
0900	Welcome
0910	Overview of the Alliance: - The Alliance concept (focus, objectives etc) - Structure (Research Groups etc) - Phase of development - Upcoming milestones
0930	Overview of the Paddy Rice Research Group - Recap on April meeting / origins of Group - Objectives for the Tsukuba meeting
0950	Alliance Stock-take: - Exploration of individual countries' efforts
1030	*Coffee break*
1100	Alliance Stock-take (continued): - Exploration of individual countries' efforts
1130	Alliance Stock-take discussion: - Analysis of research group stock-take - Preliminary identification of gaps, overlaps, collaboration opportunities
1230	*Lunch*
1330	Paddy Rice Research Group governance: - Charter discussion (feedback on specific sections) - Steering committee - Linking the Paddy Rice Group to the other Research Groups and cross-cutting issues - Linking with Partners and resource persons - Communicating internally and externally (website)
1500	*Coffee break*
1530	Future activities: - Immediate actions for the Group - Longer term actions – developing a strategy - Upcoming milestones
1700	Meeting close

Friday, September 3

One day Excursion

09:00 Leaving the Okura Frontier Hotel Tsukuba (main building)

09:40 Rice-FACE experiment site at Tsukuba-mirai city

11:00 GHG flux monitoring paddy field at Tsukuba city

12:00 *Lunch*

14:00 National Institute for Agro-Environmental Sciences
- Presentations of research topics
- GHG monitoring facility
- Natural Resources Inventory Museum

17:00 Return to the Okura Frontier Hotel Tsukuba (main building)

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ABSTRACTS

Possible Options to Mitigate Greenhouse Gas Emissions from Paddy Fields

Kazuyuki Inubushi

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Rice soils account for a large fraction of wetland ecosystems and provide a staple food to a large portion of the world's population, especially in Asia. The dynamics of C and N in submerged rice soil is different from that of aerobic soil because submerged rice soils are maintained at lower redox potentials. In submerged rice soils, decomposed C is not only mineralized to CO_2, but also fermented to CH_4, which has a potential for thermal absorption which is about 30 times higher than that of CO_2 in weight basis (Bouwman 1990). Rice soil ecosystem is basically human-made for over many years, so that mitigation options could be easier to compare with natural wetland. However long-term effects of mitigation options on soil fertility, ecosystem services and trade-off effect with other GHGs such as N_2O and CO_2, heavy metals, aquatic weeds and rice quality, should be evaluation carefully.

To mitigate CH_4 emission from paddy fields without reducing rice production, possible options are as below;
Reduce CH_4 production in soil-rice system; substrate control (Soil organic matter, straw management, aerobic decomposition before submergence, manure application etc.)
Control redox potential (water management such as mid-season drainage, installing underground draining pipes alternate wetting and drying, iron/manganese amendments, aerobic rice etc.)
Increase oxidation (oxygen transport in rice, microbes, minimum tillage etc.)

Field experiments for the mitigating CH_4 emissions from Japanese paddy fields demonstrated promising options that can mitigate the emissions significantly (10% to >50%), compared with each corresponding control treatment, without trade-off for production or N_2O emissions. Those options include composting rice straw, improving mid-season drainage practices, rice transplanting without puddling, and installing underground draining pipes. The effects of water and organic management were confirmed at the paddy fields in China, Indonesia, and Thailand.

Keywords: CH_4, straw management, mitigation, water management, microbes

Integrated Greenhouse Gas Emission from Paddy Fields in China

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Rice is the crop with the biggest production in China, but the sowing area of rice showed a declining trend since middle 1970s and was outweighed by maize in 2007. The current sowing area is about 29 million ha, with half being single rice, one quarter being early rice and remaining being late rice. Methane (CH_4) emission has been measured on over 30 sites, with varying duration since late 1980s. Measured seasonal emissions were extremely variable, ranging from 3.4 to 1274 kg CH_4 ha^{-1}. Except the widely acknowledged influencing factors such as organic amendment, water regime during rice growing season, it was found that seasonal emission from late rice is higher than that from early rice, and the latter is higher than that from single rice, likely due to the difference in the water regimes before these rice seasons. A number of estimations have been made for the total CH_4 emission from Chinese rice fields, with more recent ones being around 7.6 Tg CH_4 year^{-1}.

Nitrous oxide (N_2O) emission from paddy fields in China has been measured on over 20 sites, with seasonal emissions ranging from 0.02 to 12.6 kg N ha^{-1}. Estimated annual emission ranged from 29 to 37 Gg N.

While emitting CH_4, paddy fields in China acted as a sink of atmospheric carbon dioxide (CO_2). Average soil organic carbon content of paddy fields increased by 2.5% from 1980 to 2007, which translates to a carbon sequestration of 74 Tg for the paddy fields nationwide. The sequestrated carbon equals 5.3% of the CH_4 emitted during the same time period in terms of global warming potential (GWP).

In summary, Chinese paddy fields emit CH_4 and N_2O at 190 and 9.8 Tg CO_2-eq year^{-1}, respectively, and sequestrate carbon at 10 Tg CO_2-eq year^{-1}. Thus the GWP of paddy fields is absolutely dominated by CH_4 emission.

Keywords: *Methane, nitrous oxide, carbon dioxide*, *estimation*

GHG Emissions from Indian Paddy Fields

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Rice paddy fields are considered to be an important anthropogenic source of greenhouse gas emissions. India has more than 42 million hectare area under paddy cultivation and, therefore, efforts have been mounted to estimate the methane emission from Indian rice paddy fields with reduced uncertainties and also to understand effects of various parameters that influence methane emission from paddy fields to help in devising appropriate mitigation options. The rice cultivation area in India has been categorized under different water management regimes e.g. out of the total rice cultivation area, 52.6% is irrigated, 32.4% is rain-fed lowland, 12% is rain-fed upland and 3% is deep water rice. The irrigated rice area has been further divided into the irrigated continuously flooded (26.9%), irrigated single aeration (35.7%) and irrigated multiple aeration (37.4%) areas. This has important bearing on the total methane emission as the nation-wide studies covering major rice-ecosystems generated specific emission factors (EFs) viz. 17.48±4 g m^{-2} for irrigated continuously flooded (IR-CF), 6.95±1.86 g m^{-2} for RF-DP, 19±6 g m^{-2} for rain-fed drought prone (RF-DP) and deep-water (DW), 6.62±1.89 g m^{-2} for irrigated intermittently flooded single aeration (IR-IF-SA) and 2.01±1.49 g m^{-2} for IR-IF multiple aeration (MA) paddy water regimes (Gupta et. al. 2008). Based on these EFs, the Indian CH_4 emission from rice paddy fields for the year 1994 has been estimated as 4.09±1.19 Tg and the trend in CH_4 emission from 1979 to 2006 has been estimated in the range of 3.62±1 to 4.09±1.19 Tg y^{-1}. The ‘‘hot spot” states in India have been found to be West Bengal, Bihar, Madhya Pradesh and Uttar Pradesh with RF-FP paddy water regimes, which are the largest contributors. Efforts have also been made in India to study the effects of parameters like cultivars, soil organic carbon, organic amendments, seasons etc. on the CH_4 emission from rice paddy fields to develop scaling factors which could be used in conjunction with appropriate activity data to further reduce the uncertainties in emission estimates. Recently, the Government of India has released the national greenhouse gas emission estimates for the year 2007 according to which the CH_4 emission from rice paddy has been estimated to be 3.327 Tg for the year 2007 (MoEF 2010) based on the further refined EFs. However, the studies related to N_2O emissions from rice paddy fields are very few in India. One such study revealed that N_2O emissions from IR-IF-MA rice-ecosystem was approximately five times more than that from IR-IF-SA ecosystem indicating a trade-off between CH_4 and N_2O emissions in rice paddy fields which need further detailed investigation.

Keywords: *Rice paddy fields, methane, nitrous oxide, emission inventory, water management*

References:

Gupta, P.K. et al., Development of methane emission factors for Indian paddy fields and estimation of national methane budget, Chemosphere (2008), doi:10.1016/j.chemosphere.2008.09.042.

Ministry of Environment & Forests (MoEF; 2010), India: Greenhouse Gas Emissions 2007.

Greenhouse Gas Emission under Different Crop Management Practices in Indonesia

P. Setyanto[1], H.L. Susilawati[2], R. Kartikawati[2], M. Ariani[2], and T. Sopiawati[2]

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Reduction of GHG emission to the atmosphere is essential in order to prevent ecological destruction due to global climate change as an impact of global warming. Methane (CH_4) is one of the most important greenhouse gas (GHG) emitted from rice agriculture due to anaerobic decomposition of organic matter which has a global warming potential 25 times higher than carbon dioxide (CO_2). There are three most potent GHG emitted from agriculture, i.e. CO_2, CH_4 and nitrous oxide (N_2O). About 70% of the total CH_4 emitted from Indonesia was from irrigated rice field (SNC, 2009). The International Rice Research Institute (IRRI) has collaboration with Indonesian Agency for Agricultural Research and Development (IAARD) entitled Interregional Research Program on CH_4 Emission from Rice Field for a period of 5 years (1993-1998), focusing on rainfed lowland rice. After termination of the project, IAARD take full control of the GHG analytical equipments, and enhance the capability not only to measure CH_4, but also N_2O and CO_2. Research on GHG emission from rice field carried out by IAARD has been directed in different rice ecosystem, i.e. mineral and organic soil (peat soil). The main objectives are to obtain crop management practices that increase productivity and as well reduce GHG emission from rice field on those two different soils. Studies on peat soil was conducted to determine the effect of ameliorants, i.e. dolomite, zeolite, steel slag, animal manure, rice straw, and silicate fertilizer, on rice production and GHG emission. About 12 tons of peat soil from South Kalimantan was delivered to IAARD research institute at Jakenan, Central Java. Twelve micro-plots lined with plastic were developed to establish the peat. Methane emissions were continuously recorded using automated gas sampling device, while CO_2 and N_2O were measured with manually operated chamber. GHGs fluxes were analyzed using gas chromatography equipped with electron capture detector (ECD), thermal conductivity detector (TCD) and flame ionization detector (FID). Result from this study showed that application of dolomite and steel slag could reduce CO_2e emission as much as 27 and 29%, respectively, with significantly increase yield as compared with control. GHG emission studies on mineral soil were also conducted in an Aeric Tropaquept soil of Jakenan. Different crop management practices were established to determine which practice could reduce GHG emission without sacrifying the yield. The treatments are; farmers conventional practices, integrated crop management (ICM) with continuous flooded water regime (CF), ICM with intermittent irrigation, and system of rice intensification (SRI) with saturated and intermittent water regime. GHG emissions were recorded weekly using manually operated close chamber method. Results from these study showed that ICM technique and farmers practice with both intermittent irrigation could reduce (in average for wet and dry season) as much as 40% and

35% of CO_2e emission, respectively. SRI with intermittent irrigation could reduce as much as 42% CO_2e emission, however the yield are low as compared with control (farmers conventional practice). The advantage of having automatic CH_4 sampling device is that we could conduct small scale studies and data analysis to obtain accurate sampling of CH_4 gas based on mannual operated chamber. Results showed that a highly significant relationship (P=0.01) occur between CH_4 manual and automatic operated chamber. Methane gas sampling at 06.00-08.00 am is sufficient to determine the daily flux and three times gas sampling with interval of 30 days are sufficient to determine seasonal emission.

Overview of Research Activity toward Gas Emission in Paddy Rice Production in Vietnam

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With 4.1 millions ha of natural land, accounting by 44% of agriculture land, paddy rice cultivation is considering as the largest source of agricultural GHGs emission in Vietnam. According to the National GHG Inventory for 2000, the total national GHGs emission is 143.0 Tg CO_2 equivalent, of which 45.4% is contributed by agriculture, 35.2% by fuel use, 10.5% by land use change and forestry, 7% by industrial processes and 1.8% by waste matters. Among agricultural sector, GHG emission from rice cultivation was about 37.4 Tg CO_2 equivalent, accounting for 57.5% of agricultural GHGs or 26.1% of national GHGs. To ensure food security and other socio-economic issues, Vietnam still needs to increase rice productivity by improving varieties and intensive farming system which may enclose with increasing gas emission.

To cope with the above issue, the Government of Vietnam ratified the UNFCCC in 1994, Kyoto Protocol in 2002. Though, there has been a little systematic research on gas emission issue, the country is now trying its best effort to strengthen research on reduction of GHGs emission by submitting its first National Communication in October 2002 and "National Strategy Study on CDM". In the field paddy rice, research activities are focusing on improvement of cultivation techniques such as water management, fertilization etc. to minimize the emission of gas to sustainably maintain production to meet the country economic development.

Keywords: *Gas emission; Paddy rice*

Greenhouse Gas Emissions, Mitigation and Soil Carbon Sequestration Potential for Thailand Paddy Fields

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Currently, total paddy field area in Thailand is 11 millions ha. Out of this, about 80% is rainfed. During 1998 and 2007, Thailand total paddy field areas have increased by 1.2% per year (93,000 ha per year). On average during this period, about 94% of rainfed paddy fields were harvestable. The production yield of rainfed rice is 2.5 ton/ha, while that of the irrigated field is 4.3 ton/ha. Thus, the average yield for Thailand is only 3.1 ton/ha, one the lowest yield productivity in the world. The emissions of methane in 2000 was approximately 1425 Gg, dived in to 432 Gg from irrigated fields, 906 Gg from rainfed, 4.6 Gg from deep water rice and 82 Gg from secondary rice (irrigated). Methane emission from paddy fields contributes around 60% of the total from agricultural sector. N_2O emissions from paddy field were also estimated, based on the amount of N fertilizer applied. Out of about 0.8 million tons N applied annually, 0.44 million tons are used in rice field. This results in a direct emission of about 2 Gg N_2O annually. Greenhouse gas emission from paddy file burning was measured, but found to be relatively small.

To find the mitigation options for greenhouse gas emissions from Thai paddy fields, several field researches have been conducted. One of the most intensively studied is the mitigation through water and straw managements. Mid-season drainage at the beginning of flowering stage for 3-5 days has found to be able to reduce methane emission by 10-40%. Longer drainage period or conducted during other growing stages usually results in yield reduction or ineffective. A combination effect of drainage, straw incorporation and straw burning has recently been studied. Stubborn incorporation with mid-season drainage is the most effective way of reducing greenhouse gas emission, comparing to local cultivation practices or straw incorporation with mid-season drainage. However, the limitation of this method is it is applicable only in the irrigated area. As mentioned above, only about 20% of rice field (contributing to about 36% of total methane emission) in Thailand is irrigated. To effectively mitigate emission, research to find out appropriate measures for the rainfed field, including water managements or other approaches, is needed.

Lately, studies on the potential of paddy field soil to sequester carbon have also been conducted in Thailand. Preliminary results indicate that current practices such as straw and stubborn incorporation are not sufficient to increase or even maintain the level of soil organic carbon. Field burning additionally results in soil carbon reduction. Short-term cultivation changes such as rotating between lowland rice and upland crop have shown to result in soil carbon increase. However, it is not clear yet in the long term whether such increase will continue. In addition, other roles of paddy fields in mitigating greenhouse gas emissions and increasing farm productivity such as planting energy crops and use of rice residues for energy generation have recently been received considerable attention.

Rice Situation, PalayCheck System, and Methane Emissions in the Philippines

Eduardo Jimmy P. Quilang, Flordeliza H. Bordey, Rolando T. Cruz, Constancio A. Asis Jr. and Elmer D. Alosnos

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On this study, the rice situation in the Philippines will be assessed and presented. This was used as basis for the Philippine Rice Self-Sufficiency Plan (PRSSP). Secondly, one of the major components that will be used to attain the PRSSP is the PalayCheck system which will also be discussed. This is an integrated crop management that offers great potential to address problems in crop productivity, input use efficiency (i.e. water, fertilizers, pesticides use) and environmental safety. Lastly, the implications of the PRSSP on methane emissions will be evaluated.

Palay production in the Philippines has tripled from 5.32 million tons in 1970 to a peak of 16.82 million tons in 2008. A couple of strong typhoons caused a slight decline in palay production to 16.26 million tons in 2009. Similarly, rice production in the country increased by three-fold from 3.34 million tons in 1970 to 10.57 million tons in 2008. In 2009, the Philippines produced a total of 10.22 million tons of rice based on a milling recovery rate of 62.85%. In 2009, 74.3% of palay production or 12.08 M tons came from irrigated areas; 25.4% or 4.14 M tons from rainfed lowlands; and 0.3% or 0.05 M tons from rainfed uplands. Currently, the average yield in irrigated and rainfed areas are around 3 to 4 tons per hectare, which are less than half of what is scientifically attainable. Yields in on-farm demonstration trials that uses best crop management practices are observed at 6-7 tons per hectare. Thus, we can further increase the national rice production if we can make the national average yield closer to the yields under the best crop management practices. Philippines will achieve rice self-sufficiency if the average yield per hectare will be increased by at least 150kg in 2011, 200kg in 2012, and 300kg in 2013 with a total of 650kg increased for the next three years considering 2 Million Filipinos is added per year.

The PalayCheck system will be one of the significant components to boost the yield per hectare. The following are the checks that should be satisfied in the system: 1. Used certified seeds of a recommended variety; 2. No high and low soil spots after final leveling; 3. Practiced synchronous planting after a fallow period; 4. Sufficient number of healthy seedlings; 5. Sufficient nutrients from tillering to early panicle initiation and flowering; 6. Avoided excessive water or drought stress that could affect the growth and yield of the crop; 7. No significant yield loss due to pests. 8. Cut and threshed the crop at the right time.

Using the historical records of rice area harvested, for example for irrigated from 1970 with 1,431,940 hectares (ha) to 2007 with 2,917,012ha, and with emission factor of 2.3 kg/ha/day derived from experimental fields in the Philippines, Methane (CH_4) emissions were calculated. Increasing trend of CH_4 emissions over the past 37 years was directly related to the increasing irrigated rice fields. The emission in 1970 is 7,884.55 Gg CO_2 eq while in 2007 is 16,061.65. This has brought an increased of 8,177.10 Gg CO_2 eq or an annual average of 221 Gg CO_2 eq. The contribution of rainfed is small with 8.24 Gg CO_2 eq.

Philippines could be self-sufficient in rice and at the same time could mitigate climate change using the PalayCheck system. The PRSSP focusing on increasing yield per hectare rather than increasing rice areas will have no significant effect on increased methane production because methane is dependent on area and not so much on yield (Corton et. al, 1996). The PRSSP actually has high potential to reduce methane emission because of the efficient technologies it promotes. Some of these technologies can be found on the checks under the PalayCheck system like the practice of Controlled Irrigation (CI) that reduces significant water input and Leaf Color Chart (LCC) that reduces significant application of Nitrogen.

Keywords: Rice Situation, Self-Sufficiency, PalayCheck System, Controlled Irrigation, Leaf Color Chart, Methane Emission

Rice Production Practices in Malaysia in Relation to GHG Emissions

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Rice is the staple food of 28 million Malaysian. Event hough per capita consumption of rice has decreased over the years, Malaysia still needs to import rice as local production can only meet about 70% of her rice requirement. Rice is the third economic crop in Malaysia after oil palm and rubber. Currently rice occupies about 426,000 ha of land.

Overall contribution of GHG from agricultural activities to the total national inventory shows a declining trend, decreasing from 6% (1994, NCI) to only 3% (2000, NC2 in preparation). This is due to higher increases in emissions of other sectors. Rice production is the main contributor of methane from agriculture sector.

There are a few factors that effect GHG emission from rice cultivation in Malaysia. Firstly, almost 90% of rice area in Malaysia is under wetland condition or subjected to continuosly flooding. Mid-season drainage of intermittent flooding is not in practice here due to inability to control water. The structure of irrigation scheme is unsuitable for individual farm control. This even more difficult under rainfed rice farming. Secondly, of the total area, about 204,000 ha is under several schemes that provide irrigation facilites for double cropping resulting in increased total planted area to an equivalent of 672,000 ha on productive area. This effectively increases yearly rice production area. Thirdly, almost all rice establishment in Malaysia practice direct seeding, which effectively increases the duration of flooding in rice field. Lastly, due to the time constraint in irrigated double cropping areas for subsequent planting, most farmers dispose their field rice straw through open burning. This resulted in increase emission of methane and nitrous oxide from rice cultivation.

Methane and Nitrous Oxide Emissions from an Uruguayan Rice Field

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With its temperate climate, year-round rainfall, ample natural pastures and numerous water reservoirs, Uruguay is Latin America's major rice exporter with a national average rice production of 7670 kg ha^{-1}. There are three main rice-producing areas in the country with more than 70 % of the production concentrated in the Eastern zone. Rice is planted directly into dry soil from Oct. through Nov. Approximately 30–40 days after planting, fields are flooded using water from reservoirs or rivers and drained 15 -20 days before harvest. Therefore 2/5 of the time during the crop cycle, the soil stays in non-flooded conditions. Starter fertilizers are normally applied at seeding and mainly consist in N and P applications. Additionally farmers also apply one to two urea top-dressings, at tillering and panicle iniciation. Total applied N amounts are consistently lower (average 60 kg N ha^{-1}) when compared with major rice production regions. .

Rice crop in Uruguay shares the use of soils with cattle production. Rice production rotates with 3 to 4 years of pastures before one or two years of rice. Most frequent pasture species planted in rotation with rice are Lotus (*Lotus corniculatus* L.), white clover (*Trifolium repens* L.) and ryegrass (*Lolium multiflorum*). This production system is highly sustainable, with only minimal requirements of herbicide, fungicide, insecticide and fertilizer.

Although rice is the most important Uruguayan cereal crop it was not until the 2008-2009 growing season that a preliminary non-CO_2 greenhouse gas emission study was carried out. It consisted of a greenhouse experiment to evaluate the effect of the irrigation period and nitrogen fertilization; and of a field experiment that evaluate the impact of a ryegrass cover crop compared with a bare soil during winter and its interactions with N application in rice . Methane and nitrous oxide were monitored using the static close chamber technique. Rice culture emissions were also predicted using the IPCC methodology.

N_2O measured emissions were limited to the period before flooding after fertilization and flushing .CH_4 emission began at least 10 days after flooding coinciding with the reproductive stage of rice and with independence of the flooding date. Sowing of ryegrass after summer tillage and previous to rice during the winter was proposed as a way to temporary trap nitrogen in the system. Maximum CH_4 emissions from ryegrass fertilized with 82 kg N ha^{-1} duplicated those of the treatment without a winter cover crop.

Although these are preliminary results, even in such a different rice based cropping system to the Monsoon Asia producers, CH_4 emissions were more than twice greater than N_2O on CO_2 equiv basis. Previous paddy soil management intended to reduce N_2O emissions resulted in twice higher emissions of CH_4, emphasizing the need to consider all the system and not only the rice period and to take into account all greenhouse gases.

Interaction of Methane and Nitrous Oxide Emissions from a Paddy Field with AWD Water-Saving Irrigation Management

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To cope with global water scarcity, a water-saving rice-cropping technology called "alternate wetting and drying" (AWD), a kind of intermittent irrigation technology in which a preset driest soil moisture condition is used as the main indicator for re-irrigation, has been developed. Through dissemination activities in the Philippines, China, Bangladesh, and Vietnam, it has been confirmed that a 15-30% reduction in irrigation water use can be realized without a yield penalty, but its effects on greenhouse gas emissions has been scarcely studied. On the analogy of midseason drainage studies, it is likely that water saving has a potential to be an effective option to mitigate the net global warming potential (GWP) from rice fields when rice residue is returned to the fields. However, it is also pointed out that here is the risk that nitrous oxide (N_2O) emissions offsets reduction of methane (CH_4) emissions when rice straw is not returned to paddy fields and when N fertilizer is applied at a high rate. To determine the effect of AWD management on CH_4 and N_2O emissions and to improve the technology, we carried out a 4-year field experiment (2-hour-interval gas flux monitoring) and rain-free pot experiments at IRRI, Los Baños, Philippines (driest soil moisture criteria: -20--70 kPa at 0.15-m deep soil; 120 kg N ha^{-1} $crop^{-1}$ (for dry seasons (DS)) urea in 3 split topdressings; 4 t ha^{-1} $crop^{-1}$ rice straw (dry matter eq.) in fallow periods; rice: PSBRc80). We found that 1) AWD decreased CH_4 emissions by 60-90% during the DS compared with continuous flooding (CF); 2) a month earlier rice straw incorporation with soil further decreased CH_4 emissions by 33-75%; 3) N topdressing immediately before/after irrigation decreased N_2O emissions by 80% for a month after the 1st topdressing compared with N topdressing 2 days before irrigation; and, when this was followed by 7-day flooded conditions, it decreased to the level of CF. Our findings indicate that AWD has potential for reducing the GWP of paddy fields through both CH_4 and N_2O emissions to app. one-third under the experimental conditions.

Keywords: AWD water saving irrigation, methane, nitrous oxide, mitigation

Reducing CH_4 Emission from Rice Paddy Fields by Altering Water Management

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Percentage of atmospheric methane emitted from rice paddy is estimated at 60 Tg/yr (20 – 100 Tg/yr) which is near 10% of total global methane emission of 535 Tg/yr (410 - 660Tg) (IPCC, 1995), and which is near 30% of anthropogenic CH_4 emission. Thus, mitigation of CH_4 emission is urgently required. CH_4 in paddy soil is emanated by the activities of anaerobic bacteria which is called methane producer through reduction of CO_2 or decomposition of acetic acid, and it is transported to atmosphere through soil or paddy water surface. It is effective to control methane emission from rice paddy that period is prolonged on intermittent irrigation drainage, composted rice straw is incorporated as fertilizer instead of flesh one, or other. However, empirical approach of these kinds of experiments had not been sufficient because such a kind of experiment required significant times and efforts. In this study, we conducted demonstrative experiments to verify the effects of water management method differences in order to reduce CH_4 emission from rice paddy at 9 experimental sites in 8 prefectures. In this, we used new gas analyzer which can measure CH_4, CO_2 and N_2O at once developed by National Institute for Agro-Environmental Sciences (NIAES), Japan. In this report, we show the results in two years of this study. 'Nakaboshi' (mid-season-drainage) is one of cultivation methods in rice paddy that surface water in paddy field is once drained for about 10 days and the field is maintained like upland field to give adequate stress to rice plant for better harvest qualities and yields. Our targeted evaluation was dependencies of Nakaboshi periods lengths and Nakaboshi periods to CH_4 emission reduction amounts for total cultivation periods within harvest yield maintained.

The longer length of Nakaboshi period was prolonged, the lesser emission amounts of CH_4 decreased even after when Nakaboshi period lasted, as a whole. In some cases, for example in Kagoshima, exceptional phenomena of that significant high emission were observed at a later stage of cultivation season (around the end of August). Adjusting of Nakaboshi periods did not make effective performance in such cases. In most of cases, emission increase of N_2O was not found during prolonged Nakaboshi period.

Tier 3 Estimation of Methane Emissions from Rice Fields

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Recently, substantial modifications were made to the DNDC model to improve its performance in predicting CH_4 emission from rice fields. Following these modifications, research projects are in progress to calculate Japan's CH_4 emission inventory for rice production by the Tier 3 approach, using the revised model (DNDC-Rice) and nation-scale database on weather, soils, and the management of rice fields.

Model development. With the data on daily weather, soil, and farming management, DNDC-Rice simulates photosynthesis, respiration and C allocation of rice. Its soil biogeochemistry sub-model quantifies electron donor (H_2, DOC) supply from decomposition and root exudation, and calculates CH_4 production as well as reduction of soil Fe, Mn and S based on availability of the electron donors. On the other hand, oxidation of CH_4, Fe, Mn and S is calculates based on availability of O_2 in soil. In validation using site-scale data from rice fields with varied water regimes and organic amendments, DNDC-Rice gave acceptable predictions of CH_4 emission.

Database construction. We used GIS datasets on soil type, land use, and drainage condition (semi-quantitative draining rate and groundwater level) of croplands in Japan. Rice field was divided into polygons that represent the combination of 16 soil types, 3 classes of draining rate, and 2 classes of groundwater level. These attributes were reflected on the simulation of soil water dynamics. Values of soil properties (TC, pH, clay, Fe content) were assigned to each polygon according to its soil type. Farming management (water management, organic amendment, fertilization, etc.) was assumed to follow the published crop calendar for the major cultivar of each prefecture. Daily weather data (maximum and minimum air temperature, precipitation) at the representative point of each sub-prefectural region were used to run the model.

Regional application. At the beginning of nation-wide estimation, the Tier 3 approach was applied on selected 8 out of 47 prefectures of Japan, and the result was compared with that by the Tier 2 approach of current emission inventory. According to the current inventory, average CH_4 flux from each of the 8 prefectures was in a narrow range (137-186, with the mean at 168 kg C ha^{-1} yr^{-1}), since this approach did not take into account the difference in climate and management between the prefectures. By the Tier 3 approach of this study, in contrast, the average CH_4 flux widely varied from 28 to 469 (with the mean at 213 kg C ha^{-1} yr^{-1}), due to the various climate, soil condition and managements between the prefectures. These results indicate that such a Tier 3 approach is effective in refining the national CH_4 emission inventory and in assessing the mitigation potentials.