REFERENCES

Anh TH, Vien NV, Anh NT, Huyen TTT, Chung NV, Phuong ND (2009). *One-step RT-PCR for detection of RGSV and RRSV*. Journal of Plant Protection, **5**: 21 - 26 (*Vietnamese*).

Trung HM (1985). *Rice diseases in Southern provinces of Vietnam*. Journal of Science and Technology of Vietnam, **12**: 540 - 46 (*Vietnamese*).

Hibino H (1996). *Biology and epidemiology of rice viruses*. Annu. Rev. Phytopathol. **34**:249-74

Hiraguri A, Hibino H, Hayashi T, Shimizu T, Uehara-Ichiki T, Omura T, Sasaya T (2010). *Complete sequence analysis of Rice transitory yellowing virus and its comparison to Rice yellow stunt virus*. *Arch Virol* **155**: 243-245. DOI 10.1007/s00705-009-0557-8.

Huang Y, Zhao H, Luo Z, Chen X, Fang RX (2003). *Novel structure of the genome of Rice yellow stunt virus: identification of the gene 6-encoded virion protein.* J Gen Virol **84**: 2259-2264

Receiving date: 19/6/2012
Reviewing date: 20/7/2012
Reviewer: Dr. Nguyen Van Tuat
Approved for publishing date: 29/7/20124.

4. METHANE (CH_4) AND NITROUS OXIDE (N_2O) EMISSION FROM RICE CULTIVATION IN VIETNAM: A REVIEW

Ngo Duc Minh*, Nguyen Quang Hai, Ho Quang Duc
Soils and Fertilizers Research Institute (SFRI)

ABSTRACT

Rice is Vietnam's main food product, accounting for around 45% of gross production of food crops. Vietnam is a sustainable rice supplier, the world's fifth-largest rice producer and the second-largest (after Thailand) rice exporter in the world. Recognizing the importance of the role of rice production in the national economy and food security, the reduction of the major greenhouse gases (GHGs) (CH_4, N_2O…) from paddy fields has been paid great attention by the Government of Vietnam and is part of The National Target Program to Respond to Climate Change. The GHGs emission from rice cultivation and its negative effects have been recently studied. The main research results of methane (CH_4) and nitrous oxide (N_2O) emission from paddy field in Vietnam linked to global warming are summarized in this article. We also provide a comprehensive review of some potential GHGs emissions mitigation options.

Key words: Greenhouse gases, methane, nitrous oxide, emission, rice

I. INTRODUCTION

Over the last 20 years Vietnam has been transformed from a net rice importer to the second largest rice exporter in the world with more than 30 million tons of rice produced annually. Rice production alone contributed 45% of the gross value of agricultural output and about 90% of total annual food production (GSO, 2011). The Red River Delta and the Mekong River Delta are considered the

* Email: minhsfi@gmail.com; m.ngo@irri.org

country's two major granaries, occupying 15% and 45% of rice cultivation area, and contributing about 15% and 50% of national paddy output, respectively (World Bank, 2010). The Mekong River Delta, with its high level of productivity, has in recent years contributed half of Vietnam's total rice production and about 90 percent of its total rice exports (World Bank, 2010; GSO, 2011). On a negative side, rice cultivation can contribute to climate change via greenhouse gases (GHGs): in spite of its fairly minor contribution on a global scale, rice cultivation is a substantial source of greenhouse gases at the national scale.

II. CONTENTS

2.1. Paddy fields in Vietnam: Significant source of methane (CH_4) and nitrous oxide (N_2O) emission

Table 1. Cultivated rice area with different water management regimes in Red River and Mekong River Delta in the year 2000

(Unit: million hectares)

Water management regime	Red River Delta	Mekong Delta	Total
Constantly flooded irrigation	1.957	2.353	4.310
Intermittently flooded irrigation	0.224	1.049	1.273
Rainfed	0.326	0.690	1.016
Total	2.507	4.092	6.599

(Source: World Bank, 2010)

The total area of rice paddy land in Vietnam increased from 3.96 million ha in 1990 to 4.11 and 4.74 million ha in 1995 and 2000, respectively (World Bank, 2010). In 2010, the area of rice production fell to 4.1 million ha (GSO, 2011). In 2010, the total planted rice area was nearly 7.5 million ha, of which 66%, 25%, 4% and 5% was irrigated in lowland rice area, rainfed lowland rice, flood-prone rice, and upland rice, respectively (GSO, 2011). Thus, more than 85% of the annual cultivated rice area in Vietnam is paddy field. These rice fields provide favourable conditions for CH_4 and N_2O production and emission. The Red River Delta has the largest proportion of irrigated rice/paddy area at 90%, while the corresponding rate for the Mekong River Delta is around 70%.

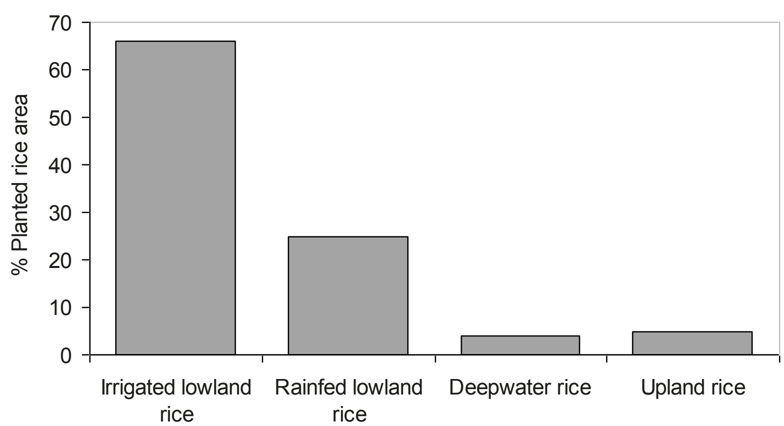

Figure 1. Contribution of different rice systems based on hydrology in Vietnam (GSO, 2011)

Agriculture is the largest GHG emission source in Vietnam. Rice cultivation is the largest source of agricultural GHGs emission. Althrough the proportion of GHG emission from rice cultivation in agriculture sector slightly decreased from 1994 to 2000 (from 64.5% to 57.5%), the amount of GHG emissions had increased during the same period from 32.75 Tg CO_2 eq to 37.43 Tg CO_2 eq, accounting for 57.5% of agricultural GHGs or 26.1% of national GHGs (World Bank, 2010). This value is expected to reach.

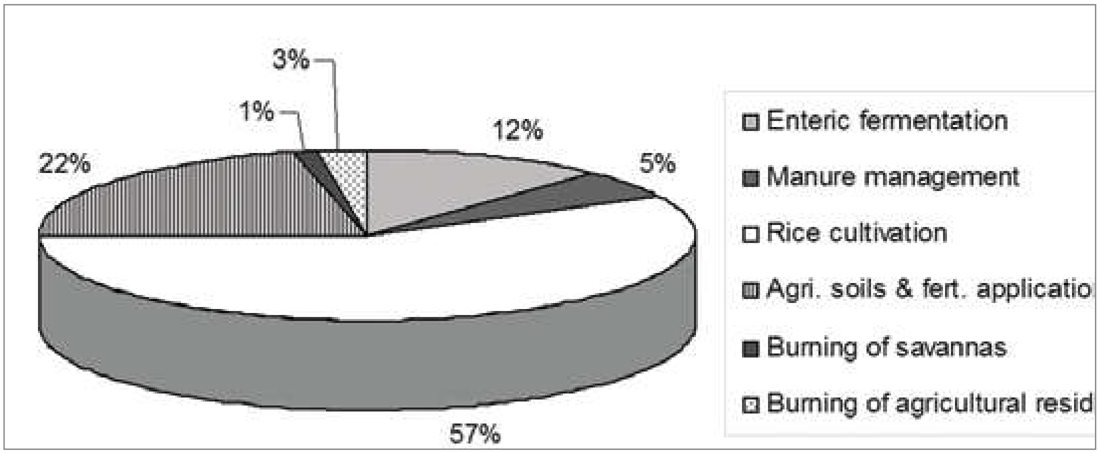

Figure 2. Proportion of GHGs emission in 2000 (CO2 equivalent) from the agriculture sector in Vietnam (World Bank, 2010)

According to IPCC's estimation, CH_4 emission from the rice fields in Vietnam is estimated to be 6.3 Tg yr^{-1} while total N_2O emission from overall cultivated area is put at 0.41 Tg yr^{-1}, (UNFCCC, 2003). USEPA applied the population growth rates to the historical emissions attributed to rice cultivation, to develop projections at five-year intervals in Vietnam. The samount of CH_4 emissions from rice cultivation in Vietnam has continuously increased from 1.755 Tg in 1990 to 1.894 Tg and 1.998 Tg in 2000 and 2010 respectively. This value has been projected to be 2.111 Tg in 2020 (USEPA, 2002).

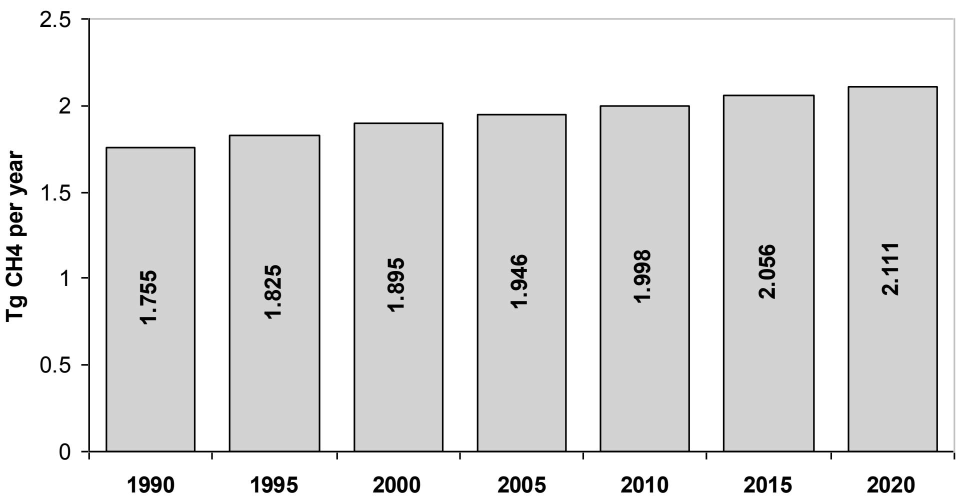

Figure 3. Estimated CH4 emissions from rice cultivation in Vietnam period 1990 – 2020 (USEPA, 2002)

In Northern Vietnam, a denification and decomposition (DNDC) model to predict CH_4 emission some irrigated rice-based systems at 3 regions along a transect in the Red River Delta (the delta lowland, the transitional midland ranges and the mountainous regions), showed that Irrigated double rice crops hadthe highest CH_4 emission with means ranging from 235 to 583 kg C ha-1. CH_4 emissions from Continuous Flooding (CF) technique were lower by 29.1% and 46.1%, than 1 and 2 Midseason Drainage (MD) technique in three sites respectively. Upland rice is not a source of CH_4, since it is grown in aerated soils that never become flooded for a significant period of time (Vu M.Q, 2006).

Table 2. CH_4 emission rate from irrigated rice-based systems under some irrigation techniques in Northern Vietnam (kgC/ha/year)

Crop system	The transitional midland ranges			The delta lowland			The mountainous regions		
	CF	1MD	2MD	CF	1MD	2MD	CF	1MD	2MD
Spring rice	47.0	23.0	15.3	78.7	51.0	41.0	nd	nd	nd
Rice – Rice	224.2	159.1	136.9	528.5	358.5	305.9	582.6	358	302.1
Summer rice	119.6	79.4	64.9	98.0	60.0	48.0	282.6	192.8	170.9
Summer rice - 1 annual crop	131.8	84.5	68.8	493	330.8	286.4	164	88.5	72.8
Summer rice - 2 annual crops	77.7	45.8	36.3	294	236	214.0	nd	nd	nd
Rice - Rice - 1 annual crop	249.5	173.7	148.9	nd	nd	nd	nd	nd	nd

(CF: continuous flooding; MD: midseason drainage; nd: not determined), (Vu M.Q, 2006)

In the Mekong River Delta, a study of rice production with less greenhouse gas emissions in An Giang province showed that the volume of GHG emissions reach its highest in flooded paddy field. Differences in residue recycling, organic amendments, scheduled short aeration periods, soils, fertilisation, and rice cultivars are major causes for variations of CH_4 fluxes in irrigated rice. Highest CH_4 fluxes are observed in fields receiving organic amendments. Lowest CH_4 fluxes are recorded in fields with low residue recycling, and multiple aeration periods. The author advised to combine the treatment of alternate wetting and drying (AWD), with using the leaf color chart (LCC) to have higher yields and less GHG emissions (Nguyen 2011).

Prediction of N_2O emission from irrigated rice-based systems at 3 case studies along transect in the Red River Delta by DNDC model showed that irrigated double rice cropping or single rice crops recorded the lowest N_2O emission with means ranging from 2.5 - 8.4 kg N ha-1, whereas N_2O emission rates were highest in summer rice - 2 annual crops system in all of 3 case studies with means greater than 16 kg N ha-1. N_2O emission in 1 MD and 2MD scenarios increased by 1.6% and 45.4%, respectively, compared with CF (baseline practice) (Vu M Q, 2007).

Table 3. N_2O emission rate from irrigated rice-based systems under some irrigation techniques in Northern Vietnam (kgN/ha/year).

Crop system	The transitional midland ranges			The delta lowland			The mountainous regions		
	CF	1MD	2MD	CF	1MD	2MD	CF	1MD	2MD
Spring rice	2.5	2.5	2.7	2.9	3.3	4.3	nd	nd	nd
Rice – Rice	2.3	2.6	3.3	4.8	5.9	8.4	3.3	3.7	5.7
Summer rice	3.6	3.5	4	nd	nd	nd	5	5	7.3
Summer rice - 1 annual crop	11.8	11.6	11.9	6.4	6.7	7.6	10.1	9.9	11.7
Summer rice - 2 annual crops	16.3	16.3	16.5	16.9	16.8	17.8	nd	nd	nd
Rice - Rice - 1 annual crop	7	7.2	7.8	8	9.8	12.4	nd	nd	nd

(CF: continuous flooding; MD: midseason drainage; nd: not determined) (Vu M.Q, 2006)

The DNDC model was used to predict and assessing CH_4 and N_2O emissions from rice cultivation at a national scale under continuous flooding (CF) and midseason drainage (MD) scenarios. CF of rice fields resulted in annual net emissions of 972-1,607 Gg C yr^1 and 16-72 Gg N yr^1. The global warming potential (GWP) for this scenario was 37-83 Tg CO_2 equivalent yr^1. MD of rice fields reduced annual net CH_4 emissions by app. 50% to 497-819 Gg C yr^{-1}, whereas N_2O emissions increased to 34-104 Gg N yr^{-1} (corresponding to increases of 112% for the minimum and 44% for the maximum value). In terms of GWP, this management scenario decreased greenhouse gas emissions to 31-74 Tg CO_2 eq yr^{-1} (corresponding to 16% and 8% decrease, respectively).

Table 4. Total GHG emission from rice field under different water management

Total emission	Continuous flooding		Midseason drainage	
	$Clay_{max}$	SOC_{max}	$Clay_{max}$	SOC_{max}
CH_4 emission (Gg C yr^{-1})	972.0	1,607.0	497.0	819.0
N_2O emission (Gg N yr^{-1})	16.0	72.0	34.0	104.0
GWP (Gg CO_2 eq yr^{-1})	37,238.0	82,708.0	31,289.0	73,611.0

The map of GWP in the Vietnamese rice systems showed two regional hotspots - he Red River Delta in the North, and the Mekong River Delta in the South. The regions with high CH_4 emissions were characterized by high temperature and high soil organic carbon content and light texture. Meanwhile, high N_2O emissions occurred in the regions dominated by upland and rainfed rice ecosystems with high content of soil organic carbon. MD showed a significant reduction in greenhouse gas emissions from rice and can be seen as a promising mitigation strategy in Vietnam (Vu M.Q, 2006).

2.2. Mitigation potential of CH_4 and N_2O emission from rice production

2.2.1. Reducing methane emissions

Studies by the International Rice Research Institute (IRRI) show that growing rice in flooded fields is a highly sustainable practice where soil health can be maintained. Water-saving technologies such as alternate wetting and drying (AWD) reduce the amount of time rice fields are flooded and can reduce the production of CH_4 by about 60-90%. IRRI is promoting AWD as an alternative management practice (see Table 5 and references in the footnote).

Table 5. Potential options for the reduction of CH_4 emissions in rice fields

Management Practice	Continuous Flooding, Organic Amendment	Mid-season Drainage, Organic Amendment	Continuous Flooding, No Organic Amendment
Alternate wetting and drying (AWD) management	Mid-season drainage (7-44%)	-	Mid-season drainage (15-80%)
	Alternate flooding/ drying (59-61%)	Alternate flooding/ drying (21-46%); Early/dual drainage (7-46%)	Alternate flooding/ drying (22%)
Organic amendments	Compost (58-63%)	Biogas Residues (10-16%)	-
	Phosphogypsum		
Mineral amendments	(27-37%)	-	Phosphogypsum (9-73%); $(NH_4)2SO_4$ (10-67%);
	Table urea (10-39%)		
Straw management	-	Fallow incorporation (11%); Mulching(11%)	-
Crop establishment	Direct wet seeding (16-22%)	-	-

Note: Values in parentheses are reduction effects for each mitigation practice or modified crop management. (Wassmann et al, 2000 & 2007).

2.2.2. Reducing nitrous oxide emissions

In Vietnam, the efficiency of nitrogen fertilizer use in rice cultivation is around 35-40% only. The site-Specific Nutrient Management (SSNM) approach with the leaf color chart (LCC) can increase nitrogen use efficiency to 50 percent or even higher so as to prevent unwanted N losses and their serious impacts on the ecosystem. Under the SSNM approach in the Red River Delta, the amount of fertilizer N was reduced by about 25% and mean annual yield of rice increased by 0.8 t/ha compared with the existing farmers' fertilizer practices (Buresh et al, 2005). The results of rice field experiments and demonstration trials conducted at 30 sites in the Mekong River Delta showed that SSNM increased fertilizer use efficiency by 10% and increased grain yield by 5-8% compared with farmers practices (Buresh et al, 2005). Use of on-farm data in the Mekong River Delta with DNDC model suggested that the use of SSNM could reduce GWP associated with reduced emissions of N_2O - a greenhouse gas - per unit of grain (Pampolino et al, 2007).

AWD may reduce CH_4 emissions but the practice can increase the production of N_2O, another greenhouse gas, which is 300 times more potent than CO_2. To mitigate the production of N_2O, water-saving technologies must be accompanied by good nutrient management. Reducing fertilizer wastage concomitantly reduces the amount of excess nitrogen in the soil which in turn reduces N_2O emissions (Wassmann et al, 2007).

III. CONCLUSIONS

Rice production plays a significant role in the global source of GHGs. Anaerobic decomposition in rice fields results in the release of substantial amounts of CH_4 into the atmosphere. While CH_4 is the most important component of the GWP from rice production, the interactive nature of nitrogen cycles in rice fields demands a consideration of the other GHGs, namely N_2O, in view of full GWP accounting. Alternate wetting and drying (AWD) that is an alternative management practice for irrigating rice can reduce the production of CH_4 by about 60-90%. N_2O emissions can be mitigated using an appropriate combination of nitrogen application and irrigation timing. Combining water-saving and nutrient management technologies can maintain yields and reduce greenhouse gas emissions from rice fields, while simultaneously reducing costs and conserving valuable inputs.

REFERENCES

Buresh R.J 2007. *Environmental impact and economic benefits of site-specific nutrient management (SSNM) in irrigated rice systems*. Agricultural Systems 93:1-24.

General Statistics Office, 2009. *Statistical Yearbook of Vietnam*. Statistical Publishing House, Hanoi.

US-EPA 2002. *Emissions and Projections of Non-CO_2 Greenhouse Gases for Developing Countries: 1990-2020*. Office of Air and Radiation, USEPA, Washington, D.C. Available in http://www.epa.gov/nonCO_2/econ-inv/pdfs/draftdevelopingcountries.pdf

Vu M.Q., (2006). *Modeling Methane (CH_4) and Nitrous Oxide (N_2O) Emissions from Cropping Systems in Vietnam: Regional Case Studies and Upscaling for Rice*. Master Thesis. Agricultural Science and Resource Management in the Tropics and Subtropics (ARTS) - University of Bonn.

Wassmann R, Jagadish SVK, Peng SB, Sumfleth K, Hosen Y, Sander BO. 2010. *Rice production and global climate change: scope for adaptation and mitigation activities*. IRRI Limited Proceedings No. 16. Los Baños (Philippines): International Rice Research Institute. 76 p.

World Bank (2010). *Potential climate change mitigation opportunities in the agriculture and forestry sector in Vietnam*. Background Paper 58102. Carbon Finance Assist Program - Vietnam. Nov-2010.

Receiving date: 12/5/2012
Reviewing date: 17/7/2012
Reviewer: Dr. Grant Singleton
Approved for publishing date: 29/7/2012

5. RESULTS OF BIOTECHNOLOGICAL APPLICATIONS IN HYBRID MAIZE BREEDING FOR HIGH YIELD, GOOD STRESS TOLERANCE

Bui Manh Cuong*
Maize Research Institute (MRI)

ABSTRACT

After 10 years of research and application of biotechnology in breeding maize hybrids, the Maize Research Institute has gained several remarkable achievements. Most notably in developing the doubled haploid (DH) breeding technology, and applying molecular markers to analyse genetic diversity and resistant ability of maize inbred lines. A nursery of DH lines was established for the development of commercial maize hybrids with high yield, good stress tolerance, such as LVN145, LVN146, LVN092, and other commercially desirable traits. A system of molecular markers has been established to effectively analyze genetic diversity, cluster heterotic groups, improve maize materials resistance to *Rhizoctonia solani*, and evaluate drought tolerance ability. Some new varieties were created using biotechnological techniques that have been applied in cultivation and have partly contributed to improving yield, productivity and production efficiency of maize production.

Keywords: Biotechnology, anther culture, DH line, genetic diversity, maize breeding

I. INTRODUCTION

Biotechnology is of high importance in developing agriculture in general and maize in particular. The Maize Research Institute has carried out studies of the application of biotechnology in breeding maize hybrids as follows:

- Studying the application of doubled haploid line developing technology;

- Using molecular markers to analyse genetic diversity, clustering of heterotic group, and drought and diseases tolerance among materials;

- Developing new high yield maize hybrids through combining traditional methods and biotechnological methods.

After 10 years of research and application, the Maize Research Institute has gained remarkable achievements in maize variety breeding.

* Email: bmcuongcnsh@gmail.com