Methane Emission from Paddy Fields in Northern Thailand

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Abstract

Seasonal variations of CH_4 flux, soil Eh and soil temperature were determined in paddy fields at Phitsanulok, San Pa Thong and Phrae for the major and the second rice croppings*. The average values of the CH_4 fluxes measured for the major rice at Phitsanulok, San Pa Thong and Phrae were 7.4, 16.1 and 22.2 mg m^{-2} h^{-1}, respectively, and for the second rice 6.6, 8.8 and 15.9 mg m^{-2} h^{-1}, respectively. The CH_4 emission from Phrae paddy field in the second rice was higher than that of San Pa Thong due to the high content of fresh organic materials and abundant water supply.

The estimated seasonal emissions for the major rice at Phitsanulok, San Pa Thong and Phrae were 17.4, 39.8 and 68.2 g m^{-2}, respectively, and for the second rice 17.9, 21.3 and 48.5 g m^{-2}, respectively. The high estimated seasonal emission of CH_4 at Phrae was attributed to the longer duration of the flooding period and higher CH_4 flux values than at the other two sites.

Additional key words: fresh organic material, global warming, methane flux, paddy soil

* Wet season rice cropping and dry season rice cropping are hereadter referred to as "major rice"and "second rice", respectively.

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INTRODUCTION

To estimate the CH_4 flux in Thailand accurately, NIAES-DOA collaborative research program was initiated in 1991. Yagi et al.[15] performed measurements of CH_4 flux from paddy fields in the central plain of Thailand. They reported the average flux of CH_4 from paddy fields at Suphan Buri, Khlong Luang, and Chai Nat. The low emission rates of CH_4 at the latter two sites were attributed to the high concentration of sulfate in soil or the high soil Eh due to the lower abundance of the reducing capacity in relation to the oxidizing capacity of the soil.

JIRCAS-DOA collaborative research had been started in 1993. Katoh et al.[5] reported CH_4 flux from a paddy field in Bang Khen, central plain of Thailand. They observed a relatively low emission of CH4 in the second rice, with an average flux of 4.3 (1993) and 6.7 (1994) mg m^{-2} h^{-1}. The low emission rates of CH_4 in the second rice were attributed to the very shallow water depth.

The area with the major and the second rice in 1993 in the northern region of Thailand accounted for 22 and 21% of the total rice harvested area, respectively. These data show that northern region is an important area for the estimation of CH_4 emission from paddy fields in Thailand. In this paper, we report the results of CH_4 emission measurements performed in Phitsanulok, Phrae and San Pa Thong paddy fields.

EXPERIMENTS

1) Experimental sites and methods

Field measurements were performed at Phitsanulok and San Pa Thong Rice Experiment Stations and the Phrae Rice Research Center in the northern region of Thailand. Soil properties analyzed by the methods which were described previously[15] are shown in Table 1. Paddy field was irrigated prior to transplanting and the surface water was maintained at depth ranging between 0 and 20 cm until the maturation stage of rice plants.

Rice varieties used, duration of the flooding period and dates of flooding, transplanting, drainage and harvest are listed in Table. 2. Rice plants (*Oryza sativa*) were cultivated according to the conventional method. After the harvest of the previous crop, the roots and approximately half of the aboveground biomass of rice plants were plowed into the paddy fields. Rates of mineral fertilizers applied (basal fertilizer and topdressing) and rice yields are shown in Table 3. Dry weight of

Table 1. Some properties of the paddy soils

	Phrae	San Pa Thong	Phitsanulok
Series	Lampang (Lp)	Hang Dong (Hd)	Alluvial complex
Taxomomy	Typic Paleaqualfs	Typic Tropaqualfs	
Texture	Silty clay Loam	light clay	light clay
pH (air-dried soil)	7.1	6.6	4.5
pH (flooded soil)	6.9	6.9	6.3
Total C (g kg^{-1})	0.89	1.03	1.4
Total N (g kg^{-1})	0.09	0.11	0.14
Available N (μ g N g^{-1})*	32	49	91
Free Fe_2O_3 (g kg^{-1})	1.2	1.5	2.2
ER Mn (μ g g^{-1})**	96	118	198
SO_4^{2-} (μ g S mL^{-1})	28	29	48

*Easily reducible manganese

Table 2. Cultivation practices and rice variety

Site	Year	Rice cultivation	Flooding	Trans-planting	Drainage	Harvest	Floofing period (days)	Rice variety
Phitsanulok								
	1992	Major	8 Aug	18 Aug	14 Nov	21 Nov	98	RD23
	1993	Second	12 Feb	12 Feb	5 Jun	12 Jun	113	RD23
Sun Pa Thong								
	1993	Major	2 Aug	17 Aug	13 Nov	15 Nov	103	RD25
	1994	Second	4 Feb	21 Feb	16 May	23 May	101	RD25
Phrae								
	1993	Major	9 Jul	12 Jul	14 Nov	28 Nov	128	RD6
	1994	Second	10 Feb	17 Feb	10 Jun	10 Jun	127	RD10

Table 3. Fertilizer and rice yield

Site	Year	Rice cultivation	Basal fertilizer (kg ha^{-1})			Topdressing	Rice yield
			N	P_2O_5	K_2O	N (kg ha^{-1})	(Kg ha^{-1})
Phitsanulok							
	1992	Major	30	37.5	0	28	Not recorded
	1993	Second	30	37.5	0	28	Not recorded
Sun Pa Thong							
	1993	Major	30	37.5	75	16	3210
	1994	Second	30	37.5	75	16	3500
Phrae							
	1993	Major	20	25	0	0	4510
	1994	Second	20	25	0	0	4310

rice straw and weeds which was measured in paddy field at the San Pa Thong Rice Experiment Station and the Phrae Rice Research Center and farmers' fields are shown in Table 4.

2) Sampling and determination of CH_4 emission, soil temperature and redox potential (Eh)

The closed chamber method was used for gas sampling from paddy fields as described by Yagi and Minami[13, 14]. Methane concentration was measured by gas chromatography (FID). Soil temperature and soil redox potential (Eh) were measured by the methods described in a previous paper[15].

Four measurements were performed during each cultivation period for the 1992 major rice (July to November) and 1993 second rice (February to June) at Phitsanulok. Three to four measurements were performed during the cultivation period for the 1993 major rice (July to November) at Phrae and San Pa Thong. Ten to thirteen measurements were performed for the 1994 second rice (February to June) at Phrae and San Pa Thong. All the measurements were performed in duplicate in the morning in each plot.

Results and Discussion

Seasonal variations of CH4 flux, soil temperature and soil Eh in a paddy field at Phitsanulok, San Pa Thong and Phrae for the major rice are shown in Figs. 1, 2 and 3, respectively. The average values of the flux were 7.4, 16.1 and 22.2 mg m^{-2} h^{-1}, respectively. Average values of soil temperature at a depth of 5 cm were 25.2, 26.7 and 26.5℃, respectively, and soil Eh at a depth of 5 cm

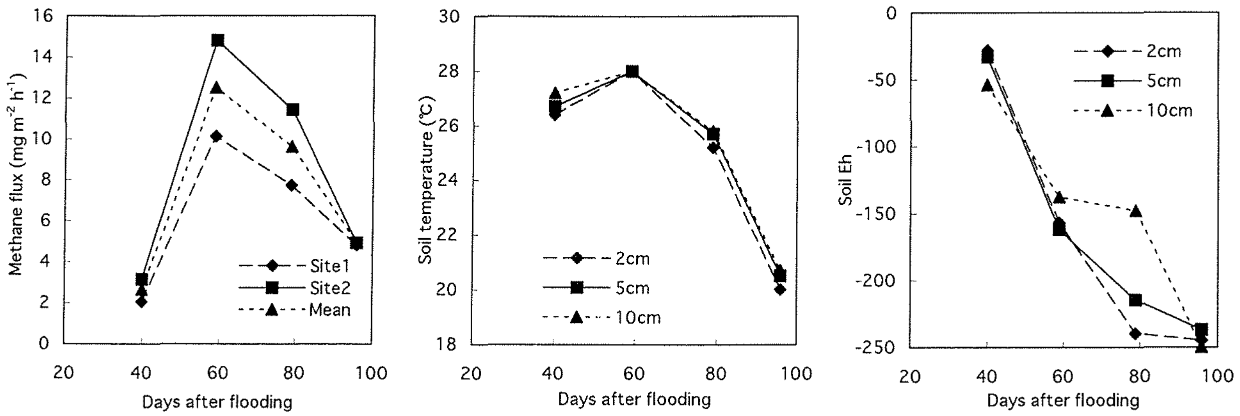

Fig. 1. Methane flux, soil temperature and soil Eh in Phitsanulok paddy field (1992 major rice)

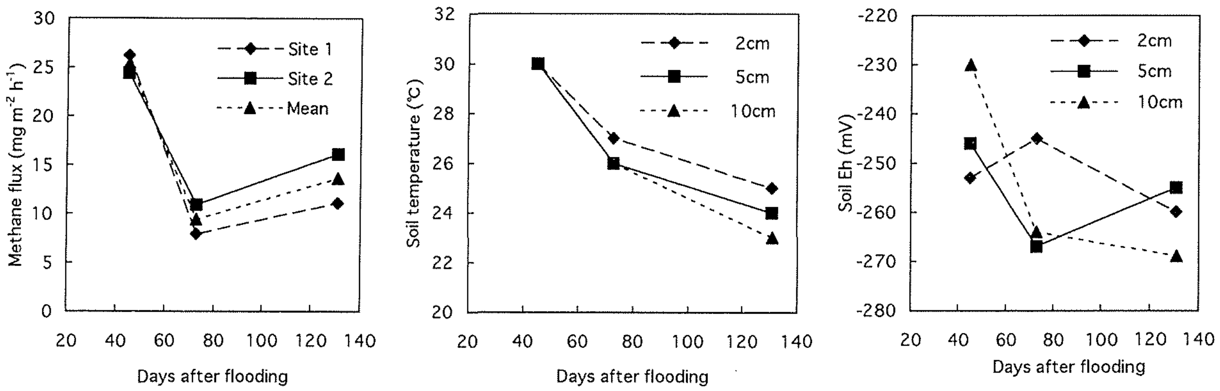

Fig. 2. Methane flux, soil temperature and soil Eh in San Pa Thong paddy field (1993 major rice)

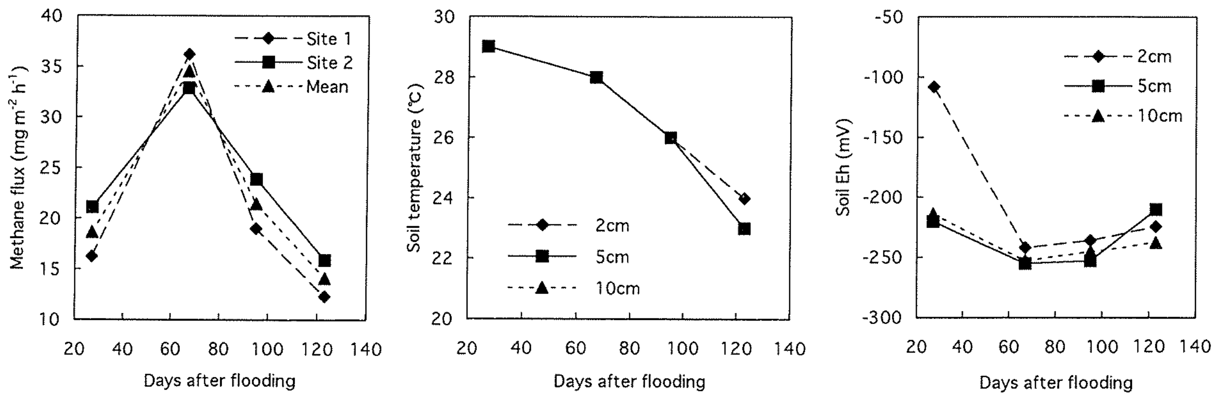

Fig. 3. Methane flux, soil temperature and soil Eh in Phrae paddy field (1993 major rice)

were -162, -256 and -235 mV, respectively.

Seasonal variations of CH_4 flux, soil temperature and soil Eh in a paddy field at Phitsanulok, San Pa Thong and Phrae for the second rice are shown in Figs. 4, 5 and 6, respectively. The average values of the fluxes were 6.6, 8.8 and 15.9 mg m^{-2} h^{-1}, respectively. Average values of soil temperature at a depth of 5 cm were 25.8, 26.8 and 26.6℃, respectively, and soil Eh at a depth of 5 cm were -31, -136 and -221 mV, respectively.

It is well known that the addition of various

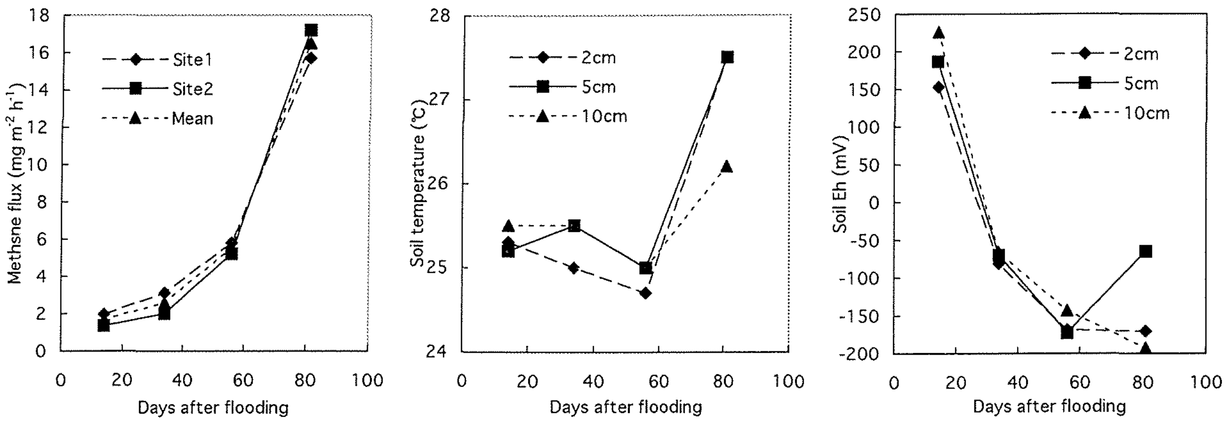

Fig. 4. Methane flux, soil temperature and soil Eh in Phitsanulok paddy field (1993 second rice)

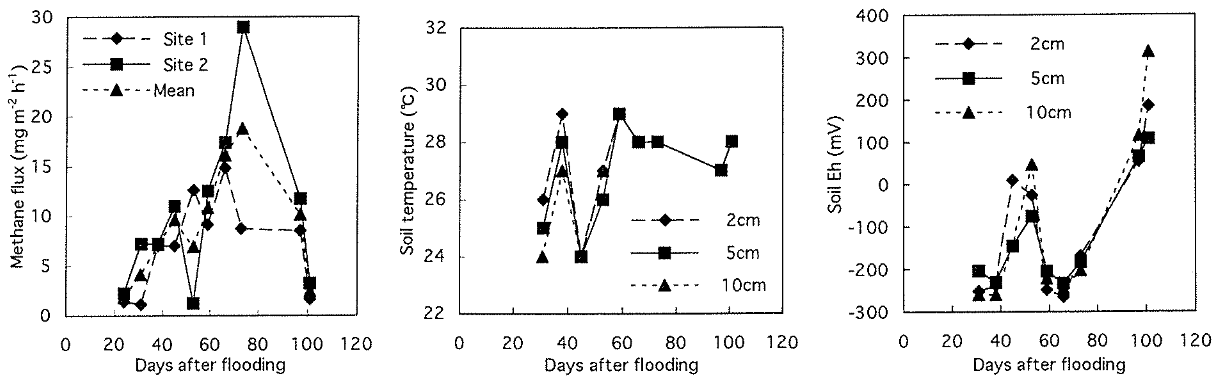

Fig. 5. Methane flux, soil temperature and soil Eh in San Pa Thong paddy field (1994 second rice)

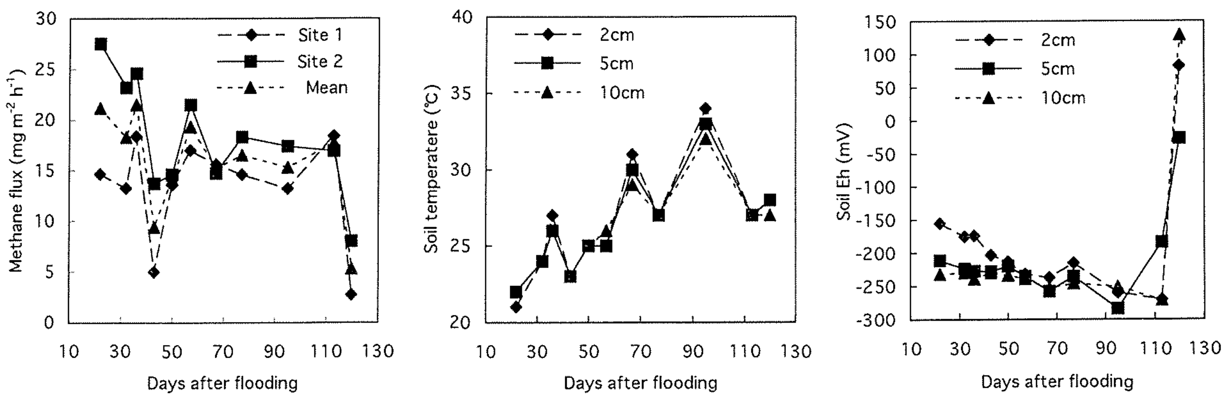

Fig. 6. Methane flux, soil temperature and soil Eh in Phrae paddy field (1994 second rice)

kinds of readily decomposable organic materials increases CH_4 production in paddy soils[7, 11, 12]. Yagi and Minami[13] showed that the application of rice straw significantly increased the CH4 emission rates. Amounts of organic matter at Phrae Rice Research Center were higher than at San Pa Thong Rice Experiment Station (Table 4), due to the cultivation of a local rice variety (RD 6). The standing water at Phrae was maintained at between 5 and 20 cm until the maturation stage of rice plants. The importance of the water supply was indicated in the previous paper[5]. Soil temperature

Table 4. Amount of stubbles and weeds

	Dry weight (g m^{-2})
San Pa Thon Rice Experimental Station	195
Prae Rice Research Center	378
Farme's field at	
-San Pa thong	127
-Phrae 1	147
-Phrae 1	138
-Uttaradit	66
-Phitsanulok 1	63
-Phitsanulok 2	105
-Tak Fa	68

is known to be an important factor for the activity of soil microorganisms. Yamane and Sato[16] observed that methane formation was negligible at a temperature below 20℃. However, soil temperature in the second rice at Phrae measured at a depth of 5 cm ranged from 22 to 33℃ with an average value of 26.4℃. These data indicated that the CH_4 emission increased rapidly due to the high content of fresh organic materials, abundant water supply and high temperature in the Phrae paddy field for the second rice. This large CH_4 emission was maintained until drainage.

On the other hand, CH_4 fluxes from the San Pa Thong paddy field in the second rice were smaller than those from the Phrae paddy field. Amount of fresh organic materials in the San Pa Thong paddy field was lower than that in the Phrae paddy field (Table 4), due to the lower amounts of biomass of the rice variety used (RD25). The standing water in San Pa Thong paddy field disappeared within 40 to 60 days after flooding. Therefore, the low emission of CH_4 in the second rice in the San Pa Thong paddy field was attributed to the low amount of fresh organic matter and the shallow water depth due to the limited amount of irrigation water in the dry season.

The flux data and estimated seasonal emission rates of CH_4 from Phitsanulok, San Pa Thong and Phrae paddy fields are summarized in Table 5. The seasonal emission rates were estimated by multiplying the averaged flux by the duration of the flooding period. The estimated seasonal emission rates from Phitsanulok, San Pa Thong and Phrae in the major rice were 17.4, 39.8 and 68.2 g m^{-2}, respectively, and in the second rice were 17.9, 21.3 and 48.5 g m^{-2}, respectively. The higher estimated seasonal emission rates of CH_4 for the major and the second rice from paddy fields at Phrae than those at the other two sites were attributed to the longer duration of the flooding period and higher CH4 flux values. Methane emission rates measured at Phitsanulok and San Pa Thong were within the range reported for paddy fields in Thailand[4, 5, 15], while the rates at Phrae were around the higher edge of the reported values. It is likely that the high emission rates at Phrae caused by the large input of fresh organic materials into the soil prior to the cultivation, as demonstrated by Jermsawatdipong et al.[4] regarding the effect of organic material application.

Many researchers reported that more than 90% of the total CH_4 was emitted through the aerenchyma of the rice plants and that diffusion or escape of bubbles are minor processes in temperate region[1, 2, 3, 6, 13]. The growth of rice plants and the development of the aerenchyma system of the rice plants play an important role in CH_4 emission[9]. The peak of CH_4 emission appears in the late growing season in most cases in the temperate zone. Measurements in Japanese paddy fields showed that the CH_4 emission started to increase nearly one month after flooding, due to the low temperature and high soil Eh[13]. On the other hand, large CH_4 fluxes in the first half of the

Table 5. Seasonal emission of methane from thai paddy fields

Site Year	Rice cultivation	Flooding period (day)	CH_4 flux (mg m^{-2} hr^{-1})	Estimated seasonal emission (g m^{-2} $seaseon^{-1}$)
Phitsanulok				
1992	Major	98	7.4	17.4
1993	Second	113	6.6	17.9
Sun Pa Thong				
1993	Major	103	16.1	39.8
1994	Second	101	8.8	21.3
Phrae				
1993	Major	128	22.2	68.2
1994	Second	127	15.9	48.5

season were observed in the 1993 major rice at San Pa Thong (Fig. 2) and the 1994 second rice at Phrae (Fig. 6). The importance of this season for CH4 emission from paddy fields was reported in studies carried out in Thailand and Indonesia[4, 8]. Taja et al.[10] found that CH_4 was actively emitted from the plowed paddy fields by spontaneous gas evolution before transplanting from sandy soil in Northeast Thailand. The large CH_4 emission at the early stage of the season indicates that the spontaneous evolution of CH_4 produced in soil due to high temperature plays an important role in the transport of CH_4 from paddy fields in the tropical region.

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北部タイにおける水田からのメタン発生

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摘　要

北部タイのPhitsanulok，San Pa Thong，およびPhraeの水田圃場において，雨季作および乾季作での水稲栽培期間中のメタンフラックス，土壌Eh，および地温の季節変動の測定を行った。雨季作栽培期間中のメタンフラックスの平均値は，Phitsanulok，San Pa Thong，およびPhraeで，それぞれ，7.4，16.1，および22.2 mg m^{-2} h^{-1}であり，乾季作栽培期間中のそれらは，それぞれ，6.6，8.8，および15.9 mg m^{-2} h^{-1}であった。乾季作における，San Pa ThongとPhraeのフラックスの違いは，土壌の新鮮有機物含量と潅漑水供給の違いによると考察された。

季節変動の測定より見積もられた栽培期間全体のメタン発生量は，雨季作において，Phitsanulok，San Pa Thong，およびPhraeで，それぞれ，17.4，39.8，および68.2 g m^{-2}であり，乾季作では，それぞれ，17.9，21.3，および48.5 g m^{-2}であった。他の２地点に比べ，Phraeにおける栽培期間全体のメタン発生量が高く見積もられたのは，長い湛水期間と高いメタンフラックスによる。

キーワード：新鮮有機物，地球温暖化，メタンフラックス，水田土壌

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