B-16.7.1 Studies on Development of Reduction Techniques for Methane and Nitrous Oxide Emissions from Agricultural Fields in Asia

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Abstract

(1) The methane flux from rice paddy fields was measured at 8 sties in China during 1993-1997. The methane emission rate was in a range of 1.6-148$gCH_4m^{-2}y^{-1}$, and was different from site to site, and year to year. The large methane emission rate was measured from un-drained rice paddy fields in non rice growing season, and possibly contributes to the total emission rate in China.

(2) An intensive five-year (1995-1999) filed program on the N_2O flux measurement in an onion field in Hokkaido, Japan showed that the emission ratio of N_2O-N to the total amount of nitrogen fertilised into the soils was 1-3 %, much higher than in the other region of Japan. And the flux of N_2O was much higher in the latter half of vegetation, indicating that N_2O could be produced by denitrification process, because a part of nitrogen fertiliser was remained in the deeper soils as NO_3^- in high concentration.

(3) The first field measurement of N_2O flux from soils in a forest in Hachi-oji located near Tokyo showed an annual N_2O emission rate was of 0.42~0.62 kg N ha^{-1}, much higher than in the other temperate region such as Europe and North America. The concentration of NO_3^- in stream water was positively correlated with N_2O flux in forest soils, and could be a good indicator to predict the rate of N_2O flux from forest soils on a watershed scale. It strongly suggests that the phenomenon of 'nitrogen-saturation' is of a crucial importance for N_2O emission from forest ecosystems.

Key Words Rice Paddy fields, China, Methane emission, Hokkaido, Onion fields, Nitrous oxide emission, Forest soils, Stream water, Nitrate ion.

1. Introduction

Asia has a huge area of agro-ecosystems, especially rice paddy fields because of Asian Monsoon climate. As the emission data of greenhouse gases from field measurements is very few, there is still a large uncertainty with the estimate of greenhouse gases from terrestrial ecosystems by IPCC. We have conducted the CH_4 and N_2O flux measurements from terrestrial ecosystems not only in Japan but also in Asian region, under the collaborative studies with many researchers and institutions in Asia, since 1990. The intensive field measurements have been carried out in rice paddy fields for CH_4 and N_2O emissions, upland fields with nitrogen fertilisation for N_2O and NO emissions, and forest soils for N_2O emission and CH_4 uptake. In this report, the major results from three intensive field studies in China and Japan will be briefly introduced.

2. Research objectives

(1) A study of CH_4 emission from rice paddy fields in China has started since 1992, in collaboration with Prof. Cai Zucong, Institute of Soil Science, Chinese Academy of Sciences, China. The purpose of this study is to have a better understanding of the CH_4 emission rate in spatial and year-to-year variation. Since China has about 25 % of the total rice paddy fields in the world, the emission rate in China could greatly contribute to the accurate estimate of CH_4 emission rate in the world.

(2) A field study of N_2O flux from upland and cultivated soils in Hokkaido, northern part of Japan, has been carried out since 1995 by Prof. Hatano, Department of Agriculture, Hokkaido University, Japan. An intensive three-year (1992-1994) field experiment on CH_4 and N_2O emission from rice paddy fields and upland soils all over Japan indicated that the emission rate of N_2O from upland and cultivated soils in Hokkaido was much higher than in the other region of Japan. The purpose of this study is to determine the annual emission rate of N_2O from upland soils in Hokkaido, and to make clear the major factors controlling the N_2O emission and the mechanism of N_2O production in soils.

(3) A filed study of N_2O emission from forest soils in Japan has been performed since 1998 by Dr.Yoh, Department of Agriculture, Tokyo University of Science and Technology. His group already revealed a condition of "nitrogen saturation", by measuring nitrate ion in soils and stream water in a watershed of forest environment in Hachi-oji iocated near the Tokyo Metropolitan area, due to the dry and wet depositions of nitrogen from the atmosphere to the forest ecosystems. The purpose of this study is to measure the annual emission rate of N_2O from forest soils in Japan, because no field measurements have been made in Japan and Asia. And the other purpose is to evaluate the effects of nitrogen saturation on N_2O emission from forest ecosystems in Japan.

3. Design of field experiment

(1) The flux of CH_4 from eight sites in major rice paddy fields in China (Fig. 1 and Table 1) was measured every week in the rice growing seasons during 1993-1997, by closed chamber method. In Chongqing where water in rice paddy fields could not be drained during no rice growing season (i.e., in winter season), the CH_4 flux was also measured because CH_4 was emitted although no rice was planted, different from other sites where water was well drained in fallow season.

(2) The flux measurement of N_2O has been measured at an onion field in Mikasa City, Hokkaido, Japan from April to October since 1995 by closed chamber method. Onion was transplanted in April after a fertilisation rate of 300 $kgN\ m^{-2}$ in average, and harvested in early September, every year. The absorption rate of nitrogen by onion plant was 129 $kgNm^{-2}$ in average, and nitrate ion was still remained in the soils after harvest.

(3) A systematic measurement of N_2O flux was made from May 1998 to December 1999, in a watershed covered with a deciduous forest in Hachi-oji located in a suburb of Tokyo Metropolitan area. Three sampling sites at ridge part, steep slope part and valley part were selected along the landscape. This watershed has been identified as a 'nitrogen-saturated' condition (nitrate concentration of 100 μM in stream water was very high,), an over-nutrition of ecosystem with nitrogen due to atmospheric deposition. The N_2O flux was also measured in two 'nitrate-type' forests (high NO_3^- but low DOC in stream water) and two 'DOC-type' forests (low NO_3^- but high DOC) in the Lake Biwa watersheds in July, September and October 1999.

4. Results and Discussion

(1) The CH_4 emission rate from rice paddy fields at 8 sties in China during 1993-1997 was in a range of 1.6-148$gCH_4m^{-2}y^{-1}$, and was different from site to site, and year to year, as shown in Table 2[1]. The maximum CH_4 emission rate of 148 $gCH_4m^{-2}y^{-1}$ was found in Yingtan where rice straw was incorporated just before late rice cultivation started, and water in the rice paddy fields could not be drained at the bottom in a hilly area. The high CH_4 emission rate of 36.2 gCH_4m^{-2} was measured from un-drained rice paddy fields in a fallow season in Chongqing. The CH_4 emission rate in growing and non-growing seasons in un-drained area of China possibly contributes to the total CH_4 emission rate in China.

(2) An intensive five-year (1995-1999) field program on the N_2O flux measurement in an onion field in Hokkaido, Japan showed that the emission ratio of N_2O-N to the total amount of nitrogen fertilized into the soils was in a range of 1-3 %, much higher than in the other region of Japan. The flux of N_2O was much higher in the latter half of growing season than in the former period, as shown in Fig.2. It strongly suggests that N_2O could be produced by denitrification process, because a part of nitrogen fertiliser was still remained in the deeper soils as NO_3^- -N in high concentration in August and September[2].

(3) The first field measurement of N_2O flux from soils in a forest located near Tokyo Metropolitan area showed that an annual N_2O emission rate was of 0.42～0.62 kg N ha^{-1}, much higher than in the other temperate region such as Europe and North America[3]. The seasonal variation of N_2O flux was positively correlated with soil temperature, probably due to humid condition under Monsoon climate. The N_2O flux was also strongly correlated with NO_3^- concentration in stream water of the watersheds around Lake Biwa. It indicates that the concentration of NO_3^- in stream water could be a good indicator to predict the emission rate of N_2O from forest soils on a watershed scale. The phenomenon of 'nitrogen-saturation' is of a crucial importance for N_2O emission from forest ecosystems.

References

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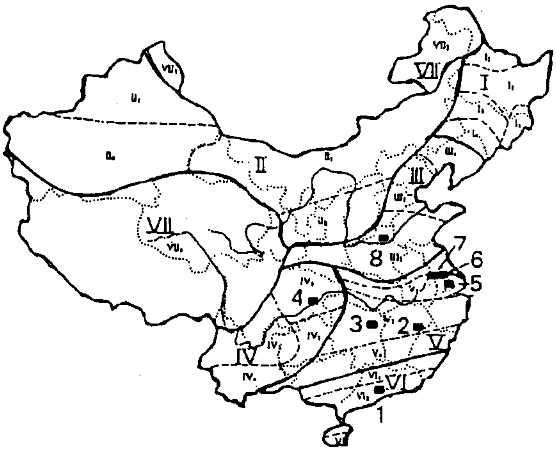

Table 1 Rice cultivation in China

region	No. cropping	harvested area (Mha/year1993)
I	single	1.647
II	single	0.372
III	single	0.755
IV	single/double	4.690
V	single/double	16.608
VI	double	6.822
VII	non	------
	Total	30,894

Fig. 1 Rice cultivation regions and the sites of field measurement
(1. Guangzhou; 2.Yingtan; 3.Changsha; 4.Chongqing; 5.Suzhou; 6.Jurong; 7.Nanjing; 8. Fengqiu).

Table 2 Annual CH_4 emission rate in rice paddy fields at 8 sites inChina during 1993-1997

Site(region)	Crop rotation	Organic matter application	Annual CH_4 emission rate($gCH_4\ m^{-2}y^{-1}$) 1993	1994	1995	1996	1997	Ave.
1. Guangzhou	rice-rice-vegetable	no		7.5	24.1			15.8
2. Yingtan	rice-rice-fallow	rice straw	148	78.3				113
3. Changsha	rice-rice-fallow	weed			48.6	58.8	83.8	63.7
4. Chongqing	rice-fallow	human excreta(exept1995)			36.3	87.1	43.5	55.6
5. Suzhou	wheat-rice	no	9.8					9.8
6. Jurong	wheat-rice	rice straw			1.9	6.6		4.3
7. Nanjing	rice-fallow	no		7.7				7.7
8. Fengqiu	wheat-rice	pig manure	1.9	1.6				1.8

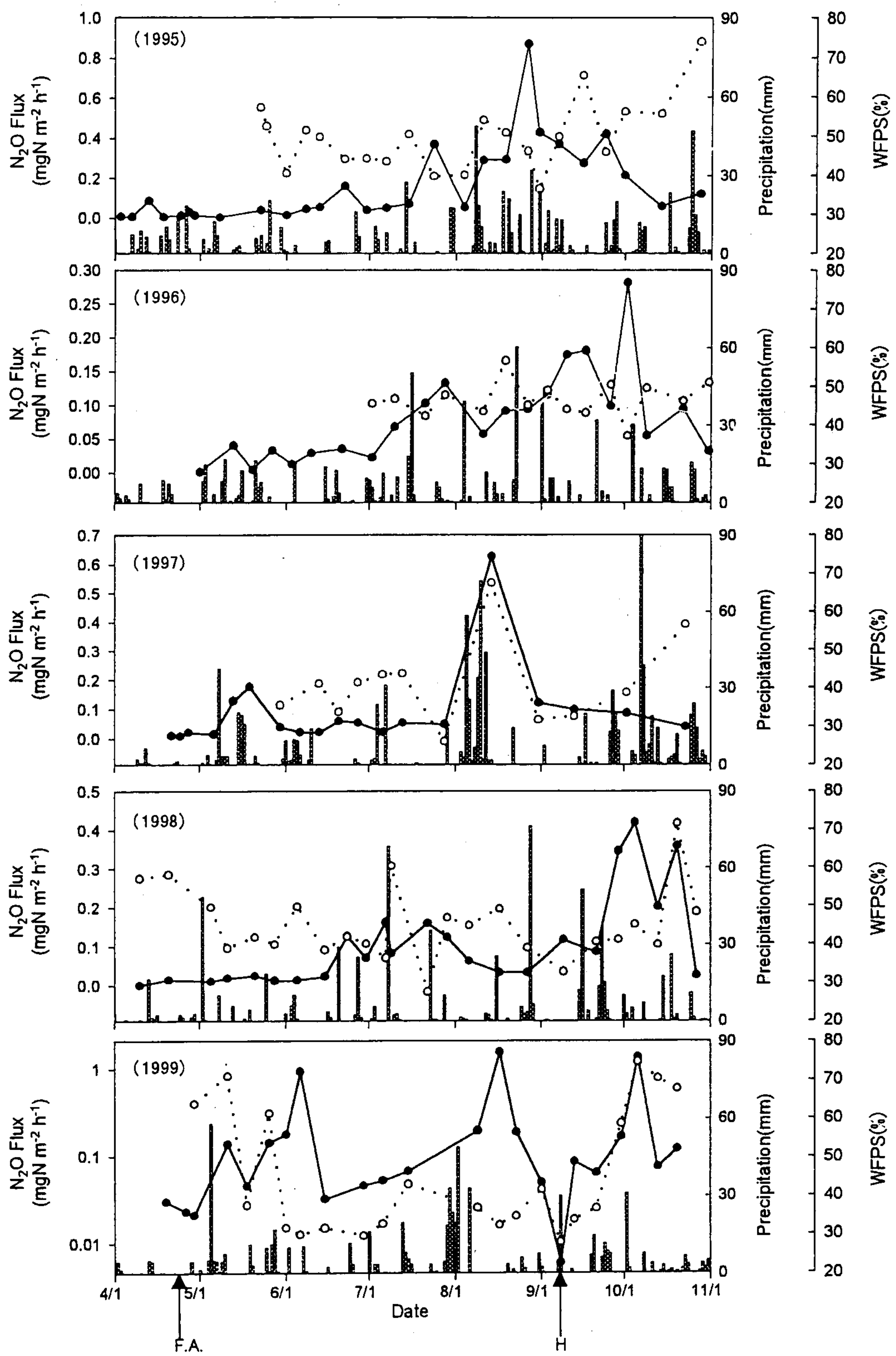

Fig. 2 Seasonal variation of N_2O flux (●), soil moisture content (○, WFPS: %) and precipitation (▒, mm) during 1995-1999.

FA: Fertiliser application, H: Harvest.

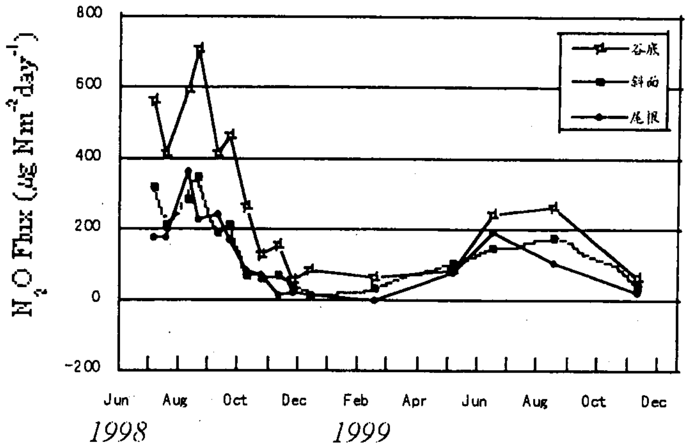

Fig. 3 Seasonal variation of N_2O flux from soils in a deciduous forest, Hachioji, Tokyo

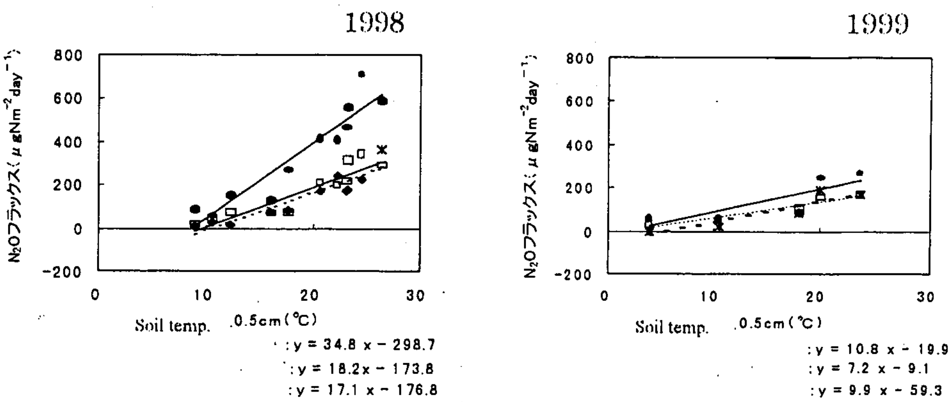

Fig. 4 Relationship between N_2O flux and soil temperate.

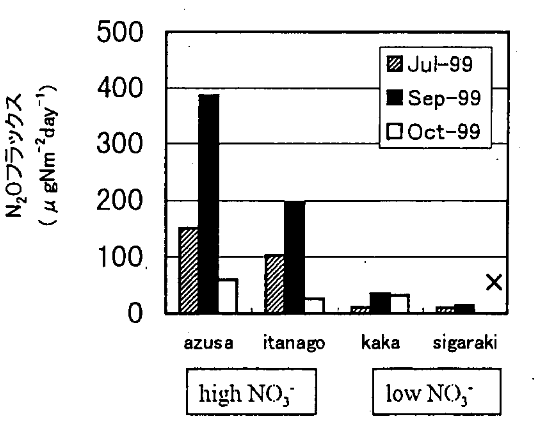

Fig. 5 N_2O flux from sites with high NO_3^- and low NO_3^- in stream water of the Lake Biwa water sheds.

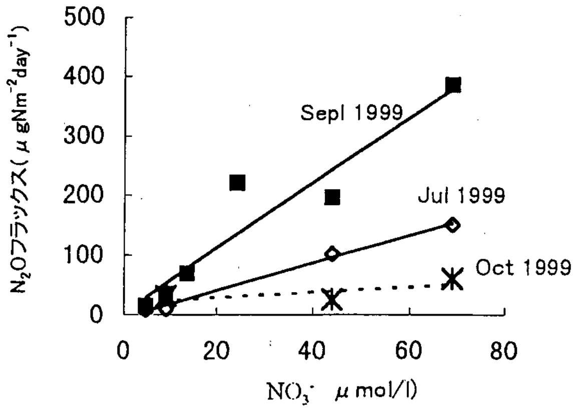

Fig. 6 Relationship between NO_3^- concentration in stream water and N_2O flux in water sheds of Lake Biwa