

MITIGATION OF METHANE AND NITROUS OXIDE EMISSION IN THE RICE FIELD USING DRAINAGE SYSTEM

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ABSTRACT

One of the important cultural practices in the tropical rice plantation is the application of water drainage system. The drainage of water in the rice field during cultivation served to improve aeration in the soil as well as promote plant growth. In addition the induced aeration during drainage effected the soil redox potential and interfere soil ecosystem, which influenced on methane and nitrous oxide emission. In Thailand, although irrigation system was introduced, various patterns of the water drainage system were conducted throughout the country. In this study, 4 different water drainage systems were conducted in the rice field in central part of Thailand There were continuous flooding system, midseason drainage, multiple drainage and local drainage. Methane emission as well as nitrous oxide emission were observed and compared with rice yield and physical change of rice plant. It was observed that the mid season drainage and the multiple drainage, with slightly reduction of rice yield, shown the average methane emission per crop 2 times lower that the continuous flood and local drainage. The nitrous oxide emission also shown the interesting information related to water drainage system. Nevertheless, it was not clear that the change of redox potential involved in the reduction of methane and nitrous oxide as it was still in range of anaerobic activities.

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INTRODUCTION

Methane is an end product of the biological reduction of carbon dioxide or organic carbon under anaerobic conditions. Methane fluxes were strongly controlled by soil carbon content, soil Eh, and soil temperature. Wetland rice soils have been shown to be an important methane source at the global scale. Rice fields contribute 9-13 % to global methane emissions. [1].

Methane emissions from rice fields appear to be decreased by field drainage and some important cultivation practices. In general, field drainage trends to increase rice yield by increasing N-mineralization and by increasing root development in the rice plant. In addition drainage is conducted to improve aeration in the rice fields and results in a possible reduction of methane production and emissions.

Previously research shown the irrigated system have the highest potential for methane emissions because the assured or continuous water supply, and continuous flooded that cause anaerobic condition in the paddy soil [2]. Methane emissions have been shown to be higher with continuous flooding than intermittent irrigation [3,4]. Methane emissions decline during the drainage to near zero and increase after reflooding [5]. Methane emission rate also varies with the timing of flooding where a late flood (76 days post planting) treatment had the highest emission 1.6 times that observed during the normal water treatment and the multiple drainage aeration treatment emitted very low seasonal emission [6]. In contrast to methane, nitrous oxide emission was introduced by aeration occurred during draining water and reflooding. Lower methane emission due to water drainage may increase nitrous oxide emission. As nitrous oxide posses much higher global warming potential than methane, the relationship of these two greenhouse gases in different drainage system should be investigated in order to reveal the influence of water drainage system as the option of greenhouse gases mitigation.

MATERIALS AND METHODS

Experimental designed

The rice fields in Samutsakorn province with soil classified as Typic Tropaquepts were used as the studied area. (Longitude 100.20 E and latitude 13.20 N). This area had been cropped continuously since last 20 years. The field measurements were taken from the second rice-growing season of 2002. Four different field drainages has been conducted as followed: 1) local method drainage according to local irrigation practice, 2)continuously flooded represented long period flooded since the 7 days after plant to 15 days before harvested. 3)mid season drained, Midseason drainage: 6 days drain at 64 days after plant (flowering period and 4)multiple aeration 3 intermittent drained periods of 2 days duration, drain at 3, 6, and 9 weeks after initial flooding... .

The common rice irrigation practices in Samutsakorn province has been applied in this study. The fertilizer 16-20-0 was applied at 20 days after

planted as the basal fertilizer which 156.25 kg/ha. Nitrogen as urea was applied as the top dressing fertilizer at 29 days after planted. The cultivars plant was Suphanburi 1, the photoperiod insensitive non-jasmine rice cultivars that required 120-125 days from planting to maturity. Shoot length 125 cm and grain yield is approximately 5,000 kg/ha. The wet seedling with 187.5 kg of rice per ha was applied to field on August 12, 2002. The fields were flooded at 7 day after planted and water level in each field was controlled at the same level (5-10 cm) excepted draining periods.

Methane measurement

Methane fluxes were usually measure once a week except during the draining periods where they were measured everyday other day. An acrylic chamber 0.6x0.6x0.85 (height) m. was used for methane measurements. An acrylic chambers made from 6 mm thick acrylic equipped with small fan (radian 3 inches) on the top of the chamber in order to air circulation inside the chambers. In addition, thermometer 0-100 °C was attached on the ceiling of the chamber for measure inside chamber temperature. In order to accomplish the close system during sample collections, the chamber was placed into 5 cm depth in flooded rice soil.

Sampling of gases from the acrylic chambers was done in a 2 hours cycle allowing four measurements of the methane inside each chamber, at 30 minutes intervals each measurement. Gas samples were collected with a syringe and transferred to the evacuated vial bottles stopped with butyl rubber septa.

Methane concentrations were determined with gas chromatography model GC 14B (Shimadzu), with unibead-C column. Column temperature 100 °C, injection temperature 120 °C, FID detector temperature 300 °C, Carrier gas flow 65 ml/min, injection volumn 0.5 ml.

Methane emissions were determined from the rate of change of concentration in a set of 4 samples taken over a 30 minutes sampling period. The samples sets of methane concentrations were plotted versus time, using linear regression. Methane fluxes were calculated from concentrations changes in the chamber with time at 30, 60, 90, and 120 minutes after the chamber was placed on the field, using the equation

$$F = 0.714 S h (273/(273+T)) \quad [7]$$

Where F is methane flux in mgCH₄/m²/h, S is the linear increase of methane concentrations increase with time, h is the available height of the chamber, and T is the inside box temperature.

Nitrous oxide measurement

Nitrous oxide concentrations were determined with gas chromatography equipped with ⁶³Ni electron capture detector (ECD).

Calibration was performed using N₂O standard gas at the concentration 1 ppm (Scotty II co., Ltd.). Column temperature 65 °C, injection temperature 150 °C, ECD detector temperature 300 °C, carrier gas flow 60 ml/min, injection volume 1 ml.

Nitrous oxide emissions were determined from the rate of change of concentration in a set of 4 samples taken over a 30 minutes sampling period. The samples sets of nitrous oxide concentrations were plotted versus time, using linear regression. Fluxes were calculated from concentrations changes in the chamber with time at 30, 60, 90, and 120 minutes after the chamber was placed on the field, using the equation

$$F = \rho(V/A) (dC/dt) [8]$$

Where F is Nitrous oxide flux in mgN₂O/m²/h, ρ is the density of N₂O-N at the pressure and temperature measured inside the chamber, V is the above-ground surface volume of the chamber, A is the cross-sectional area of the chamber, and dC/dt is the increase in N₂O concentration inside the chamber with time. The dC/dt was determined from the linear regression of a set of the four data points obtained during a measurement period.

Soil Redox potential

Soil redox potential was measured using portable platinum electrodes (HANNA instruments model HI 9025). The electrode, calibrate with redox solution for platinum electrodes, HANNA HI7020, before use was inserted in the rice soil at approximately 5 cm depth.. Sufficient time (~ 5 min) was given for reading to get the stabilized before recording.

RESULT AND DISCUSSION

Methane Emission

It was found as shown in figure 1. that the methane emission from difference drainage methods showed difference pattern of emission . In local practice and continuous flooded fields, where the drainage period was applied during early flowering period(day 55-60) and after harvesting period, high methane emission peak was found during flowering period (day 75-88) . It was also noted that with midseason drainage and multiple aeration , where the drainage were applied during flowering period (day 73-79 and day 73-76) , high methane emission peaks were not observed . This finding lead to the lower overall emission of the two later drainage fields as shown in table 2. The deviation of the highest seasonal emission from continuous flooding (35.81 g/m²) to the lowest from multiple aeration (16.91 g/m²)was more than 52.8 percent . When compare to local practice, the seasonal emission of mid season drainage (18.76 g/m²) and multiple drainage (16.91 g/m²) were 40.2 % and 46.2 % lower than local practice field, respectively.

Continuous flooded field with higher seasonal methane emission than the local practice field, produced closed proximity number of grain

yield. While the midseason drainage and multiple drainage although showed half reduction of seasonal methane emission but the grain yield were lower , particularly with multiple drainage system. The percentage of yield reduction , compare to the local practice, were 6.8 % from midseason drainage and 11.4 % for multiple drainage, respectively.

Table 1 Methane emissions from 4 difference drainage rice fields.

	Methane emissions		Grain yield (g/m ²)
	Daily average, (mg/m ² /d)	Seasonal (total), (g/m ²)	
Local method	277.40	31.43	438
Continuously flooded	318.19	35.81	405
Mid season drainage	176.37	18.76	408
Multiple drainage	143.12	16.91	388

Reduction-oxidation potential of the 4 treatment fields were also investigated during the experiment. The results showed that redox potential was increasing change when water was drained out and dropped again when the flooded water back to the field.

Nitrous Oxide Emission

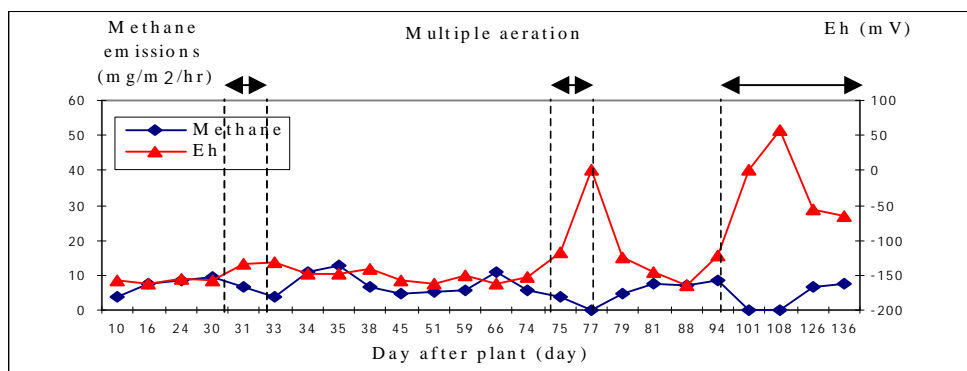
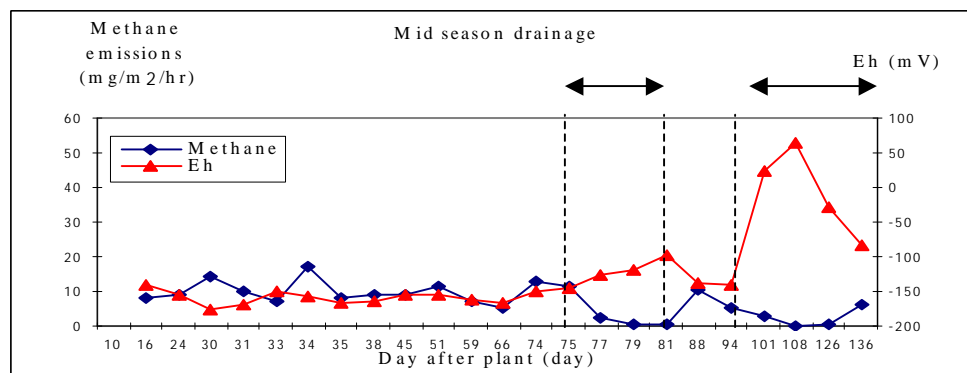
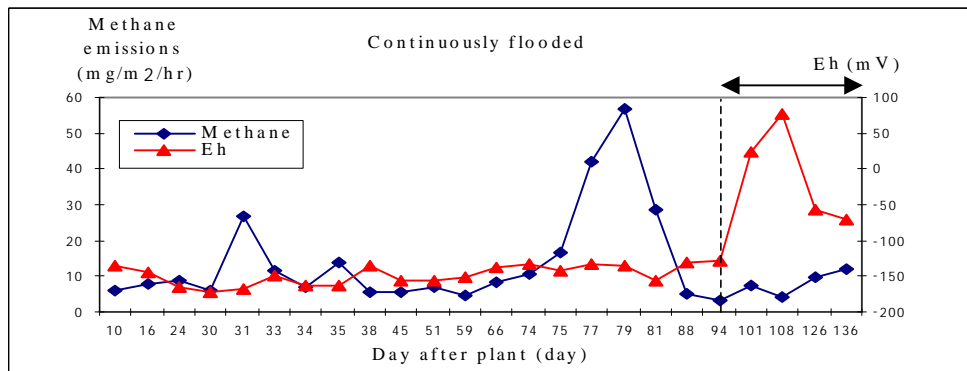
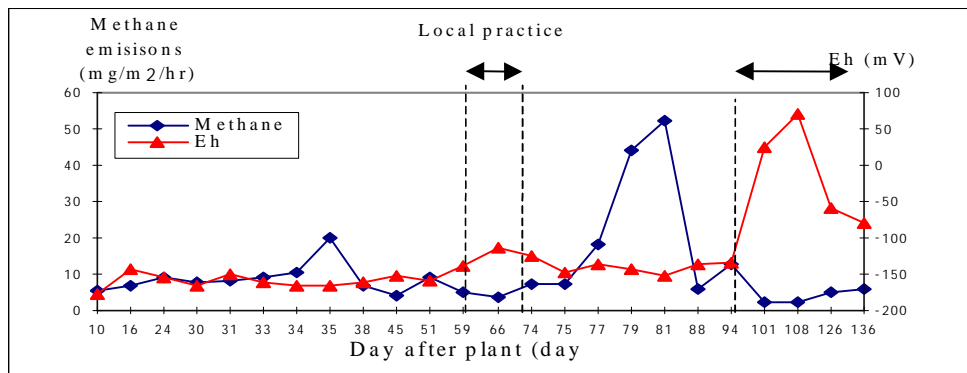
The result in figure 2 showed irregular pattern of nitrous oxide which were different within the four treatments. However as water draining lead to the increasing of soil redox potential, an increasing trend of nitrous oxide emission was observed Table 2 showed the daily average emission and the total seasonal emission of nitrous oxide from the four different drainage fields. It was found that the emission from local method and continuous flooded field were at close proximity value but lower than midseason drainage field. The lowest emission was from the multiple aeration field.

Multiple drainage, with low methane emission also showed low nitrous oxide emission when compare to other treatments. In general, drainage system introduce aeration to soil and promote nitrous oxide formation. In the case of multiple drainage, although two short drainage times (3 days) were employed, but the emission was lower than the midseason drainage with one drainage time of 6 days. We believed that, as seen by the redox potential increment, the drainage time play the important role in introducing nitrous oxide emission. Shorter drainage time might not be sufficient for nitrous oxide to development. Therefore multiple drainage showed the lowest nitrous oxide emission and methane emission despite the lowest grain yield.

Table 2 Nitrous oxide emissions from 4 difference drainage rice fields.

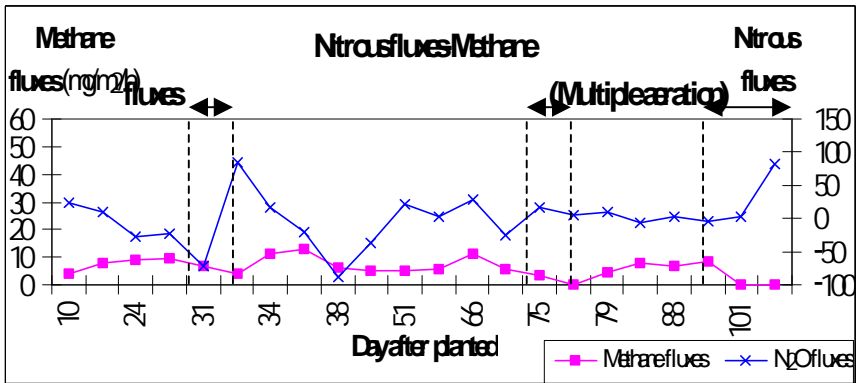
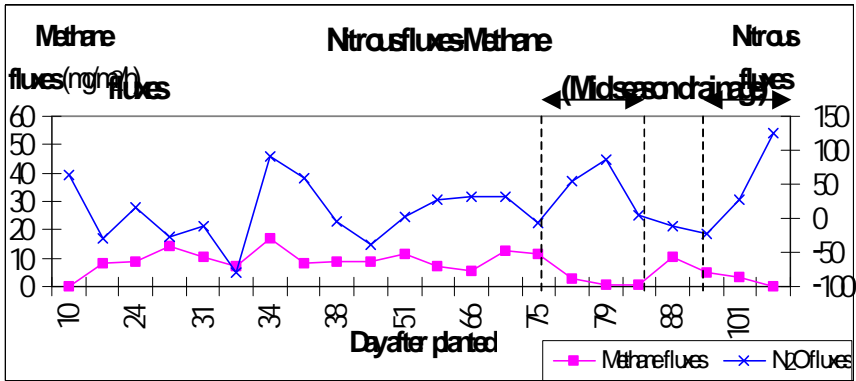
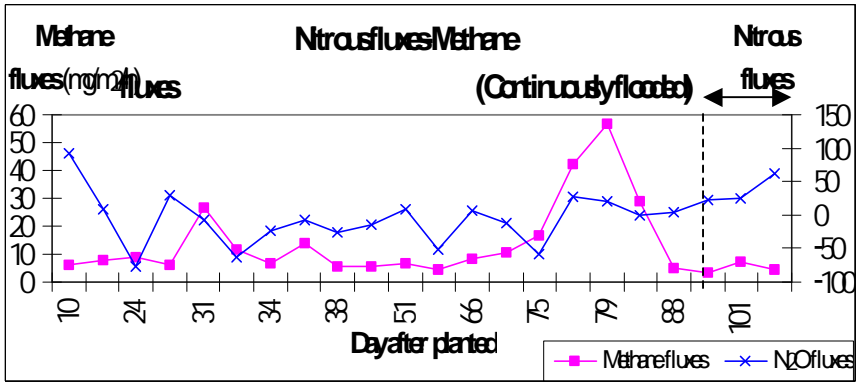
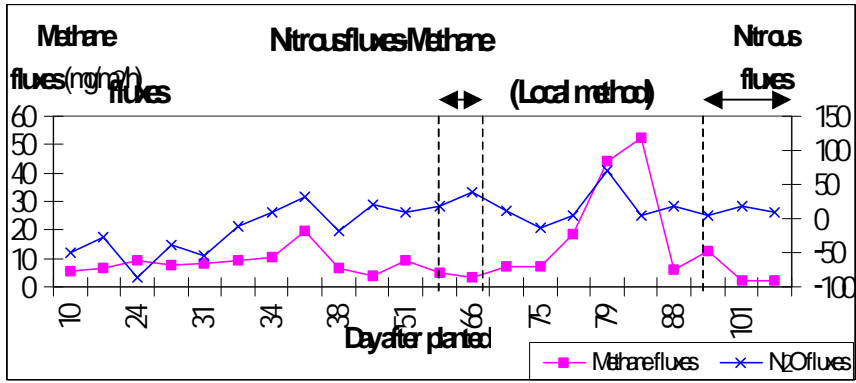
	Nitrous oxide emissions	
	Daily average, (ug/m ² /d)	Seasonal (total), (ug/m ²)

Local method	11.46	1.2
Continuously flooded	11.30	1.2
Mid season drainage	18.97	2.0
Multiple drainage	9.66	1.0



↔ Drainage day

Figure 1. Methane emission and soil relox potential from 4 different drainage rice fields



↔ Drainage time

Figure 2 . Methane emission and nitrous oxide emission from 4 different drainage rice fields

CONCLUSION

Drainage system influence methane emission as well as nitrous oxide emission from rice field. Multiple drainage and midseason drainage at flowering period can help mitigate methane emission. Nevertheless the rice yield of these two irrigation systems were 6.8 and 11.4 percent reduction while more than 40 percent of methane can be reduced. Nitrous oxide emission was influenced by drainage day rather than number of draining. Short drainage time lead to less methane emission. To maintain high rice yield and low emission of methane and nitrous oxide, midseason drainage during flowering period with shorten draining time (3 days) is recommended.

ACKNOWLEDGEMENT

The authors would like to thank School of Energy and Materials, The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi. Sincere gratitude to Energy Policy and Planning Office, Ministry of University affair as well as Thailand Research Fund for the financial support.

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