The effect of water regime and soil management on methane (CH_4) emission of rice field

IOP Conf. Series: Earth and Environmental Science **157** (2018) 012012 doi:10.1088/1755-1315/157/1/012012

The effect of water regime and soil management on methane (CH_4) emission of rice field

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Abstract. Mitigation of CH_4 emission of rice field is becoming a serious issue. The Agricultural Environment Preservation Research Station in Central Java conducted a field study to investigate the effect of water regime and soil tillage on CH_4 emission from paddy fields. Treatments consisted of two factors. The first factor was water regime, *e.g.*, 1) continuously flooded 5 cm, 2) intermittent irrigation and 3) saturated water condition at 0-1 cm water level. The second factor was soil management, *e.g.,* 1) normal tillage, 2) zero tillage + 3 sulfosate ha^{-1} and 3) zero tillage + 3 L paraquat ha^{-1}. Most of treatments gave a significant reduction of total CH_4 emission between 34 – 85% during the wet season crop as compared to normal rice cropping practice, while in the dry season the CH_4 reduction ranged between 16 – 92%. No-tillage with non-selective herbicides combined with intermittent/saturated irrigation system significantly reduced methane emission without significantly affecting rice productivity as compared to normal tillage with continuous flooding (farmers practice)

1. Introduction

Irrigated lowland rice system account for about 80% of the world harvested rice area and 92% of total rice production. Methane (CH_4) is one of the gases released from an anaerobic decomposition of soil organic matter. Flooded rice soil contributes as much as 25% or ~ 100 Tg CH_4 on an annual basis [1]. The projected increase of rice production during the coming decades [2] is expected to result in further increase in CH_4 fluxes to the atmosphere if prevalent cultivation practices continue [3, 4, 5] Current recommendations to minimize CH_4 emission in rice are based mostly on adapted rice varieties, intermittent irrigation and management of crop residues under full cultivation. No research has been carried out on the effect of no-tillage on CH_4 emission. Further, Indonesian data on the effect of water regime on CH_4 emission still need to be further validated under different soil and climatic condition.

This study reports the results of two experiments on the effect of no-tillage on CH_4 emission of a paddy field under different water regimes.

2. Materials and Method

2.1. Research Site
Two field experiments were conducted during the wet season (November– March), and dry season (April-July), at Jakenan, Central Java, Indonesia. The soil properties were relatively high acidity, low CEC and low organic matter content. The soil was classified as Incept sol with a silt loam texture.

2.2. Experimental layout and Soil Management
The experiments covered two cropping cycles (wet and dry season) with a short fallow period in between. Rice was grown under irrigated lowland conditions during the two consecutive seasons. Treatments consisted of two factors: water regime (A) and soil management (T). The factor A treatments consisted of three different water regime *e.g.,* 1) continuously flooded 5 cm (A1), 2) intermittent irrigation (A2) and 3) saturated water condition at 0-1 cm water level (A3). An illustration of the water treatments is shown in figure 1. Factor B treatments were: 1) normal tillage (T1), 2) zero tillage + 3 L ha^{-1} (TOUCHDOWN SL480) (T2) and 3) zero tillage + 3 L ha^{-1} paraquat (GRAMOXONE SL200) (T3). The treatments were arranged in 3 x 3 factorials and the experimental design was randomized complete block with three replicates. The experimental plot size was 6 m x 4 m. IR 64 rice cultivar was used in this study and transplanted at 25 days after nursery sowing.

Soil cultivation for T1 treatment was carried out one day before rice transplanting. Herbicides sulfosate and paraquat were sprayed at 9 and 4 days before rice transplanting, respectively. Inorganic fertilizer in the form of urea, SP-36 and KCl was applied at the rate of 120 kg N ha^{-1}, 60 kg P ha^{-1} and 90 kg K ha^{-1}, respectively. Water level in the plots was controlled daily.

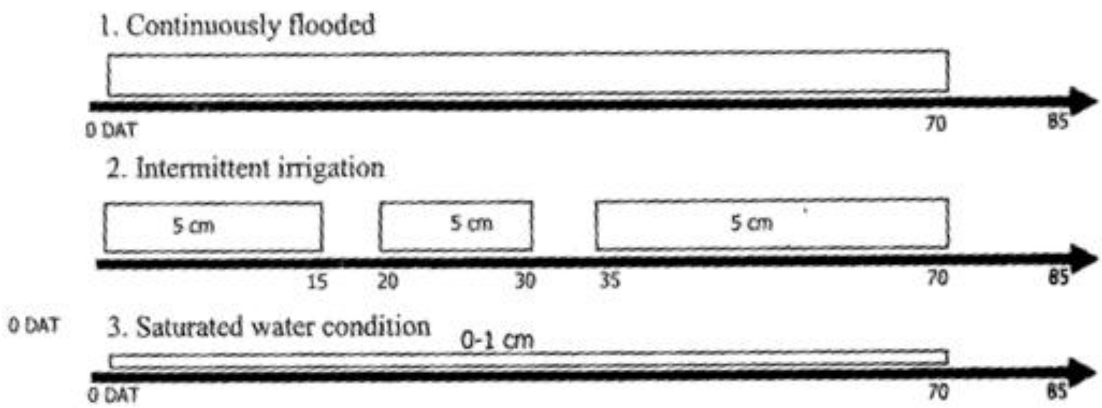

Figure 1. Illustration of water treatments *i.e.* 1) continuosly flooded 5 cm, 2) intermittent irrigation and 3) saturated water condition at 0-1 cm water level

2.3. Methane Flux Measurement
Methane fluxes were recorded every four days using the closed chamber method originally described [6]. Gas samples from each of the plots were collected using a 5 mL plastic syringe at four different intervals i.e. 3, 6, 9 and 12 minutes. Methane gas concentration inside the syringe was analysed using gas chromatograph Simadzu GC 8A equipped with flame ionization detector and a 3 m length and 1 mm diameter of porapak N column. The GC performance required for such analyses are; 1) column temperature: 75^0C and 2) injector/detector temperature: 90^0C. During gas sampling, the temperature increase and the headspace of the chamber were also recorded. This parameter is important for CH_4 flux calculation. Methane flux calculation was derived from the equation described [7].

2.4. Data Analysis

Data of CH_4 emission and yield parameters from field experiment i.e. rice production, plant height, tiller number and biomass, were analysed using analysis of variance (ANOVA). The treatment means were compared using Duncan Multiple Range Test (DMRT) and Least Significant Difference (LSD).

3. Results and Discussion

3.1. Season CH_4 Flux

The patterns of CH_4 flux from rice field as affected by water regime in two consecutive seasons are shown in figure 2 and figure 3.

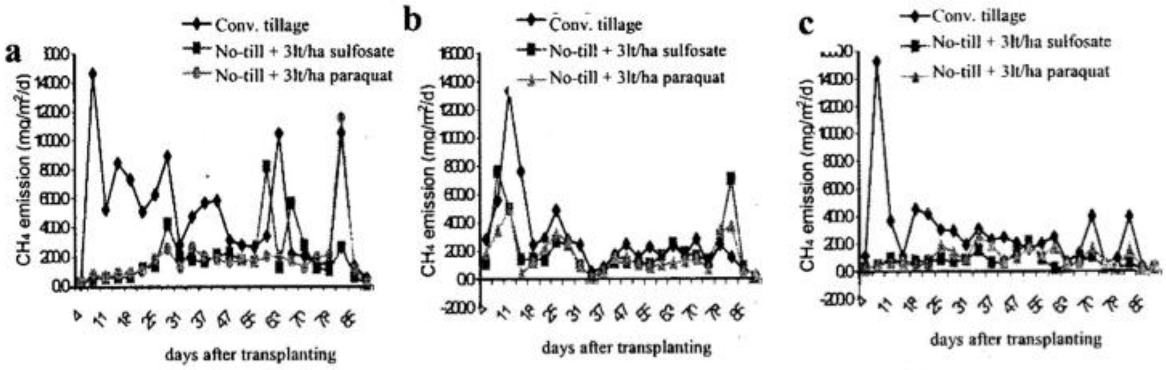

Figure 2. Seasonal CH_4 flux pattern of three different water management practices: a) continuously flooded, b) intermittent irrigation, and c) saturated water condition during wet season.

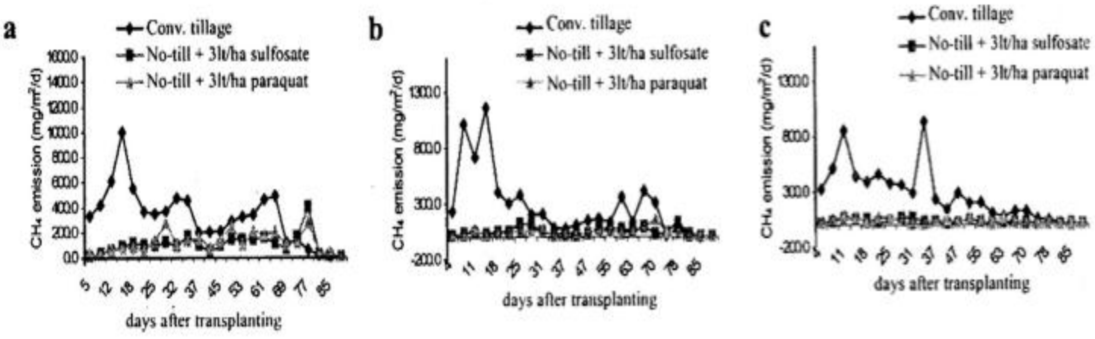

Figure 3. Seasonal CH_4 flux pattern of three different water management practices: a) continuously flooded, b) intermittent irrigation, and c) saturated water condition during dry season.

Methane flux for continuously flooded treatment (A1) started to increase within the first two weeks after flooding with an average 29.7 mg CH_4 m^{-2} h^{-1} in the wet season and 22.8 mg CH_4 m^{-2} h^{-1} in the dry season. After two weeks, the fluxes slightly decreased with an average 16.2 and 13.6 mg CH_4 m^{-2} h^{-1} for the respective season. Other irrigation treatments (A2 and A3) showed the same pattern but with different intensities. For intermittent (A2) the average flux in the first two weeks was the same in both seasons i.e. 26.5 mg CH_4 m^{-2} h^{-1}, while in the latter stage it emitted as much as 7 mg CH_4 m^{-2} h^{-1} and 6.5 mg CH_4 m^{-2} h^{-1} respectively. Saturated irrigation (A3) was showing the lowest flux with the average of

9.4 and 11.2 mg CH_4 m^{-2} h^{-1} in the two respective seasons. The average CH_4 emission reduction by implementing A2 and A3 treatment as compared to A1 was 54.7% (23.95%) and 80.1% (11.25%) respectively during the wet season crop, while in the dry season it reduced as much as 55.7% (12.15%) and 79.4% (14.07%). A study conducted [8] on different water management also showed similar results. Two or three peaks have been usually observed in most field studies on CH_4 emission [9]. The first peak is associated with the decomposition of soil organic matter or plant materials from the previous season. The second and third peaks are associated with the rice plants since they are not observed in unplanted fields [10].

3.2. Total Seasonal CH_4 Emission, Grain Yield and Plant Growth Parameters.

Table 1 shows that the water regime significantly influenced CH_4 emission. Continuously flooded water regime (A1) showed the highest seasonal CH_4 emission compared with intermittent irrigation (A2) and saturated 0-1 cm water depth (A3). The pattern was constant in the wet and dry season period. The result of this study were in line with observations of several authors [11, 12, 13, 14, 15, 16, 17, 18, 19, 20].

Table 1. Total CH_4 emission treated with different water regime as soil tillage

Treatment	($kg\ CH_4\ h^{-1}\ season^{-1}$)	
	Wet Season	Dry Season
A1 = Continuous flooding	303.08 a	255.24 a
A2 = Intermittent (5 cm)	132.31 b	55.09 b
A3 = Saturated (0 – 1) cm	137.56 b	53.11 b
T1 = Normal tillage	253.95 a	160.81 a
T2 = No-tillage + 3 L h^{-1} sulfosate	189.07 b	105.98 b
T3 = No-tillage + 3 L h^{-1} paraquat	129.92 b	96.65 b
A1T1 = Continuous flooding + Normal tillage	422.66 a	285.27 a
A1T2 = Continuous flooding + No-tillage 3 L h^{-1} sulfosate	158.33 c	241.05 ab
A1T3 = Continuous flooding + No-tillage 3 L h^{-1} paraquat	180.85 c	239.41 b
A2T1 = Intermittent + Normal tillage	246.47 b	91.90 c
A2T2 = Intermittent + No-tillage 3 L h^{1} sulfosate	177.05 c	43.74 cd
A2T3 = Intermittent + No-tillage 3 L h^{-1} paraquat	143.71 cd	23.69 d
A3T1 = Saturated + Normal tillage	240.10 bc	105.26 c
A3T2 = Saturated + No-tillage 3 L h^{-1} sulfosate	61.54 d	33.18 d
A3T3 = Saturated + No-tillage 3 L h^{-1} paraquat	88.12 d	26.83 d

Number in the same column followed by common latter for treatment A and T are not significantly different ($P<0.05$) by LSD, and interaction by DMRT.

Treatment A1T1 showed the highest seasonal CH_4 emission compared with the other treatments. In the same A1 treatment with different T treatments, *i.e.*, T2 and T3, total CH_4 emission was suppressed. The same pattern was also recorded with A2 an A3 treatments. Those treatments increased methane emission if combined with T1, and the decreased it when combined with T2 and treatments. These situations were recorded in both wet and dry season experiments. Very treatments were showing significant differences on rice grain yield indicating that the treatments did not significantly affect rice for productivity (table 2).

Table 2. Yield (kg ha^{-1}; mc14%) at different water regime and soil tillage

Treatment	Soil Tillage						Average	
	T1		T2		T3			
Water Regime	WS 2002/03	DS 2003	WS 2002/03	DS 2003	WS 2002/03	DS 2003	WS 2002/03	DS 2003
A1	5167.3	5144.0	5123.6	4656.7	4723.0	5274.3	5004.7 a	5025.0 a
A2	4814.3	4543.0	4725.7	4435.7	4535.3	4323.0	4701.7 b	4535.9 b
A3	4597.7	4321.7	4665.3	4243.7	4571.0	4372.0	4611.3 b	4312.b
Average	4859.8	4670.6	4838.2	4445.3	4619.8	4754.4		

Number in the same column followed by common latter for treatment A and T are not significantly different (P<0.05) by LSD

4. Conclusion

The result of the two field studies shows that no-tillage following the application of non-selective herbicides such as paraquat (GRAMOXONE SL200) or sulfosate (TOUCHDOWN SL480) can significantly reduce methane emission from Indonesia rice paddy fields. The reduction is higher during the dry than the wet season. Methane emission are further reduced when no-tillage is combined with intermittent or saturated irrigation. In the two experiments no tillage did not affect rice productivity significantly as compared to normal tillage with continuous flooding (current farmer's practice). Reduction of methane emission is one further potential benefit of no-tillage rice in the tropics. This combined with short term economic benefits for farmers such as lower water consumption, lower cultivation cost and increased planting index could lead to reconsider opportunities for no-till rice in tropical Asia.

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