ALTERNATIVE TECHNOLOGIES TO SUPPRESS METHANE EMISSION IN AGRICULTURAL PRACTICES IN INDONESIA

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ABSTRACT

Acceleration of greenhouse gas (GHG) emission from agricultural lands is very much dependend on harvested area and common practices by farmers. Based on several experiments and observations of methane emission from farmers' ricefields indicated that the emission can be reduced to the lowest level by improvement of soil tillage, irrigation, variety, fertilizer and organic matter application. Methane emission was highly suppressed with intermittent system (25 kg CH_4 ha^{-1} $season^{-1}$) compared with continous flooding system (143 kg CH_4 ha^{-1} $season^{-1}$). However, by these techniques rice yields decreased. Applied organic matter under dry land condition was decomposed aerobically so that only small amount of methane emitted from the soil. Methane emitted when the field start flooding. Therefore, total methane emission on rainfed lowland will be very much dependent on the duration of flooding and the residue of the available organic matter. Methane emission from different rice varieties ranges from 151 kg CH_4 ha^{-1} $season^{-1}$ (IR64 variety) to 330 kg CH_4 ha^{-1} $season^{-1}$ (IR72 variety). There is no indication that methane emission correlated with rice grain yield so that it is possible to find varieties having high yield and low methane emission.

Keyword : Agricultural land, methane, mitigation, intermittent irrigation, contionous flooding.

ABSTRAK

Percepatan emisi gas-gas rumah kaca (GRK) dari lahan pertanian sangat tergantung pada luas panen dan cara budidaya yang diterapkan petani. Hasil percobaan dan pengamatan pada pertanaman padi sawah milik petani mengindikasikan bahwa emisi GRK dapat dikurangi sampai batas minimal melalui perbaikan pengolahan tanah, irigasi, varietas, pemupukan dan penggunaan bahan organic. Emisi metana sangat tertekan dengan perlakuan system irigasi berselang (25 kg CH_4 ha^{-1} $musim^{-1}$) dibandingkan dengan system penggenangan yang kontinyu (143 kg CH_4 ha^{-1} $musim^{-1}$). Namun demikian, cara seperti itu dapat menurunkan produksi. Penggunaan bahan organic pada keadaan lahan kering dapat didekomposisi secara aerobik sehingga hanya sebagian kecil metana yang terimisi. Metana diemisikan pada saat lahan mulai digenangi. Oleh karena itu, emisi metana dari lahan sawah sangat tergantung pada lamanya penggenangan dan banyaknya residu bahan organic. Emisi metana dari berbagai varietas padi berkisar antara 151 kg CH_4 ha^{-1} $musim^{-1}$ (IR64) hingga 330 kg CH_4 ha^{-1} $musim^{-1}$ (IR72). Tidak ada indikasi bahwa emisi metana berkorelasi dengan produksi gabah sehingga masih terbuka kemungkinan mendapatkan varietas dengan produksi yang tinggi, tetapi rendah emisi metananya.

Kata kunci: Lahan pertanian, metana, mitigasi, irigasi berselang, penggenangan kontinyu.

INTRODUCTION

Agricultural practices in the future will face a very complex situtation, since they are seriously required to fulfill increasing demand of their products quantitatively and qualitatively. On the other hands, this sector will become less attractive compared with other sectors due to

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difficulty to obtain high profits and to find good lands and labors, agricultural activities should not cause environmental disturbances such as pollution of pesticides and fertilizers, soil erosion and greenhouse gas (GHG) emission which may cause global climate change.

This paper presents several alternatives of technologies to suppress emission of CH_4 without depressing crop yields or benefits or even increasing them. The approaches are as follows: (1) to understand the processes of CH_4 production, destruction, transportation and emission, (2) to select technologies which are capable to suppress CH_4 emission without sacrifying crop yields, and (3) suppression of CH_4 with adopting mitigatioin strategies should also be related to the improvement of soil condition, effieciency and benefits.

Emission Flux of Greenhouse Gases

Greenhouse gases which related with agricultural activities are as follows: (1) methane (CH_4) on flooded ricefiels, (2) nitrous oxide (N_2O) on dry land or non-flooded condition. Although CH_4 emissioin from agricultural lands is higher than N_2O emission, the heat effectivity per unit weight of N_2O is 32 times higher than CH_4. Therefore, N_2O emission from agricultural lands is also important.

Conditions and the rates of methane production, oxidation, transportation and emission depend on several factors as follows: (1) methane production occurs if the lands are flooded (anaerobe/reductive) and the rate of production is dependent on the amount and sources of carbon such as soil organic matter, applied organic C (farmyard manure, free manure, straw), plant debris, root exudates, and appropriate amount methanogenic bacteria, (2) methane oxidation and decays occur under dry condition (aerobic, oxidation condition), root oxidazing power, and activities of methanotropic bacteria, (3) methane is transported through aerenchem vessel of rice plant, release of gas bubbles from soil surfaces which is accelerated by physical disturbance during cultivating activities, and (4) total methane emission, therefore is a resultant of three processes above, plus the periods of each process.

Production of N_2O gas occurs during dry condition of land namely under aerobe or oxidative condition, while the rates of production is dependent on the amount and kinds of N sources such as organic matters in soils and from application, root exudates, plant debris, and from N fertilizers. Activities of nitrification and denitrification bacteria are also very important in determining the rate of N_2O emissioin. However, the rate of N_2O reduction or decays have not been known yet and is considered unimportant. Transport of N_2O gas from soil to air occurs through the soil pores. Therefore, the total flux of N_2O gas from the soil is a resultant of those factors above and the period of each process.

The conditions of technology for being considered as an alternative for mitigation are as follows: (1) no yield declining or even increasing crop yield when the technology is adopted, (2) increase efficiency in utilizing natural resources, inputs (fertilizers, pesticides), labors, and capitals, (3) those technologies have to suppress GHG emissiion effectively. Several examples of those technologies are presented as follows : (1) intermittent irrigation; (2) organic matter management; (3) selecting rice varieties; (4) fertilizer application.

Selecting rice varieties which have certain characteristics may supress GHG emission without decreasing rice yield (Parashar *et al.*, 1990; Makarim *et al.*, 1996). It because there are wide variability of rice characteristics such as tolerant to salinity, ion toxicity, drought or resist to pests and diseases. However, the selection needs more intensive work.

Several indicators of varietal characteristics that related to GHG emission are as follows: tiller number, aerenchime diameter, total biomass, growth duration, and root oxidizing power.

Tiller number per gill positively correlates with methane flux (Mario *et al*., 1991). The oldest tiller within a hill emits CH_4 gas higher than other tillers (Kimura, 1992). The heavier root biomass or total biomass, the more methane emitted (Sass *et al*., 1990), whereas Neue and Roger (1993) also reported that rice grain yield also positively correlated with methane emission.

MATERIAL AND METHODS

Field experiments were conducted in Pati districts, Central Java in rainy and dry seasons of 1996 and 1997. The treatments of experiments are as follows: (1) water control: continously flooding, intermittent irrigatioin and saturated water content; (2) organic matter management: farm yard manure (FYM), rice straw and control; and (3) rice variety: IR64 as a standard, Cisadane, Membramo, Dodokan, IR36, IR72, Btang Anai. Experimental design of each treatment is a Randomized Complete Block design with three replications. Methane emission was measured using manual sample procedure as follows: Boxes made of plexiglass were equipped with fan (to mix air inside the box), port (where the syringe is inserted into it to sample mixture GHG and air). Boxes are installed in the field at the time of sampling only. Samplings were done on each plot at 4 minute-intervals, 4 times at 6.00-8.00 AM. Methane readings were done by means of Gas-chromatography (GC). Methane concentration was calculated based on the reading of CH_4 methane standard (10.1 ppmv) and compared with the readings of the samples. Methane flux then calculated by finding the slope of linear regression between CH_4 in the box (in mg/m2) as Y axis and time of measurement (in minute) as X axis.

RESULTS AND DISCUSSION

1. Intermittent Irrigation

Water condition on lowland ricefield determines physicochemical characteristics of the soil, such as redox potential (Eh), soil acidity (pH), nutrient availability etc. and directly and indirectly will affect microorganism activities in the soils, including bacteria which are actively in GHG formation and destruction.

Water management which is commonly practiced on irrigated lowland ricefields is continously flooded. Most farmers believe that rice plants required flood water condition during crop growth. On intermittent irrigation system, water ais applied during certain periods such as every 4, 5, 6, or 7 days, so that the fields are not always flooding. This method will utilize water more efficiently. Effects of irrigated conditions (irrigated versus rainfed) on methane emission and rice yields are presented in Table 1. Four seasons, methane emission from rainfed system was a half to one third of that from irrigated one. On rainfed system rice yield is almost the same as in the irrigated one, except in the first season. On the other experiments (Table 2), methane emission was highly suppressed with intermittent system or with continous water saturated system. However, by these techniques rice yields decreased.

It indicates that on rainfed system or intermittent irrigation, water on the fields may not be dry for long period so that the plants will not suffer from drought. Good water control, therefore may decrease methane emission without decreasing rice yield or even increasing.

Table 1. Effects of water conditiion, irrigated or continous system versus rainfed or non-continous system on methane emission and rice yields, Jakenan, Pati, Central Java (Makarim *et al*., 1996).

Water condition	Methane emission (kg CH_4/ha/season)	Rice yield (kg/ha)
Rainy season 1993/1994		
Irrigated/flooded	197	7074
Rainfed/non-continous flooded	26	4381
Dry season 1994		
Irrigated/flooded	155	2908
Rainfed/non-continous flooded	60	3807
Rainy season 1994/1995		
Irrigated/flooded	145	4666
Rainfed/non-continous flooded	90	4903
Dry season 1995		
Irrigated/flooded	256	3886
Rainfed/non-continous flooded	89	3570

Table 2. Effects of water application on methane emission and rice yields, Jakenan, Pati.

Methods of watering	Methane emission (kg CH_4/ha/season)	Rice yield (kg/ha)
1. Continusly flooded	142,6	6588
2. Intermittent	25,0	4999
3. Water saturated, onflooded	78,8	5890

2. Organic matter management

Organic matter is a carbon source which is beneficial for soil microorganism, as a source of nutrients for crops and it is important for soil physical improvement. However, organic C is also a source for CH_4 production, while organic N is a source for N_2O gas production. Therefore, organic matter management as well as soil and matter condition determine GHG emission.

Chemical composition and molecules structure such as easlily degradable substrates and C/N ratio determine the easiness of organic matter destruction, while water condition (aerobe or unaerobe) determines the direction of the reactions to reach the final products. Aerobic degradation of organic matter will not produce methane, but tend to produce N_2O. Whereas, unaerobic degradation will produce methane and very small amount of N_2O.

Returning fresh rice straws into wet or flooded ricefields is a wrong habit that has been practiced for a long time by rice farmers. This practice is not only increasing methane emission, but also may cause iron and/or organic acid toxicities on rice plant on several soils. Several experiments show that application of rice straw 1-2 months before ricefiels flooded may reduce methane emission as much as 15-50% compared with direct application at the beginning of flooding. Composting of rice straw or straw application into dry ricefields may become more useful, because nutrient availability increases while methane emissioin decreases.

Field experiment at Jakenan rainfed on the application of different organic matter sources on methane emission and rice yields are presented in Table 3. During dry periods of gogorancah system, namely in the beginning of crop growth, applied organic matter was decomposed aerobically so that only small amount of methane emitted from the soil. Methane emitted when the field start flooding. Therefore, total methane emission on rainfed lowland will be very much dependent on the duration of flooding and the residue of the available organic matter. Effect on rice yields is also similar, which depends on soil water condition and the products of organic matter decomposition.

Experiments in other countries also indicated that application of 12 ton compost/ha emits less methane 40-62%) compared with application of 6 ton fresh rice straw. In China, incorporation of sewage sludge from biogas generation into ricefields depress methane emission as much as 60% compared with direct application of the fresh one (Wasman *et al.*, 1994). This method recycles plant debris from agricultural lands through fermentation during biogas generation and return it into agricultural lands again. By ths method methane emissiion decreases, and obtain biogas as an energy source for farmer's household.

Table 3. Effects of organic matter application on methane emission and rice yields for four seasons (Makarim, *et al.*, 1996)

Kinds and rate of organic matter	Methane emission kg CH_4/ha	Rice yield kg/ha	Methane emission kg CH_4/ha	Rice yield kg/ha
	RS 1994/95		DS 1995	
Without organic matter, on rainfed system	90	4903	89	3570
2.5 ton FYM/ha, on rainfed system	78	4127	96	3510
5.0 ton FYM/ha, on rainfed system	84	5085	101	3170
Without organic matter, on irrigated system	145	4666	256	3890
	RS 1995/96		DS 1996	
Without organic matter, on rainfed system	51	4830	50	4380
5 ton rice straw/ha, on rainfed system	64	5300	68	4610
5.0 ton FYM/ha, on rainfed system	46	4920	85	4530
Without organic matter, on irrigated system	106	4370	154	4620

3. Selecting Rice Variety

Field experiment at Pati revealed that methane emissiion from different rice varieties ranges from 151 kg CH_4/ha/season (IR64 variety) to 300 kg CH_4/ha/season (IR72 variety) (Table

4). However, there is no indication that methane emission correlated with rice grain yield. Thus, it is possible to find varieties that emit less methane but produce higher yields on the same ricefields.

Table 4. Variability of methane emission and rice yields of several rice varieties on irrigated lowland, Pati, Jawa Tengah

Rice variety	Growth Days	RS 1996/97		DS 1997	
		Emission kg CH_4/ha	Yield kg/ha	Emission kg CH_4/ha	Yield kg/ha
IR64	105	151	4915	166	3563
Cisadane	125	310	6336	332	4030
Membramo	105	269	5146	184	3864
Dodokan	98	280	3251	259	3110
IR36	105	218	6459	-	-
IR72	115	-	-	330	4629
Batang Anai	108	-	-	189	5121

CONCLUSION

1. There many alternative technologies in agricultural sector which can be adopted by farmers to reduce methane emission without sacrifying yield.

2. Suppression of greenhouse gases in agriculture sector often results in improvement soil productivity and rice production.

3. The more efficient the agriculture practices are, the less GHG emission will occur.

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