

MODEL FOR ESTIMATE METHANE EMISSIONS FROM DRAINAGE IRRIGATED RICE FIELDS.

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Abstract

Water management is the major important factor affected on rice production as well as on methane production from flooded rice soil. On the basis of available information on rice cultivation, removing floodwater induces aeration to the rice field soil and therefore inhibits methane production by ethnogeny, which leads to reduction of methane emission. To estimate methane emission from irrigation rice fields, model implementation is useful. However, the accuracy of estimation should be concern. In this study we focused on the effects of field drainage on methane emissions by using empirical model. The hypothesis of the model, with the influence on soil redox potential (Eh) to methane emissions, based on Eh change during cultivation and draining interval which other field properties such as soil pH, soil temperature during draining period were included.

The exiting empirical model to estimates methane emissions has been modified according to field observations in irrigated cultivation area in Thailand. The data from a single rice-growing season in native rice field without organic fertilizer application was used to validate the model. The results also compared with data from rice field in Texas. It is noted that model shown acceptable confine patterns of methane emission with the draining activities in the fields.

1 Introduction

Methane is an important greenhouse gas; it is 20-25 times more radiatively active than carbon dioxide [1,2,3] and strongly influences the photochemistry of the atmosphere. It has been estimated that the increase in methane concentration may have contributed about 15% to anthropogenic greenhouse effects. The concentration of methane in the atmosphere has more than doubled over the last 200 years, and in particular, has increased by about 50% in the last 40 years. The average global concentration of methane in the atmosphere was 1,720 parts per billion by volume (ppbv) in 1994, a 145 percent increase from the pre-industrial concentration of 700 ppbv [3]. It is estimated that 60 to 80 percent of current CH₄ emissions are the result of anthropogenic activities.

Wetland rice soils have been shown to be an important CH₄ source at the global scale. The concentrations of all of them are increasing in the atmosphere. Estimating emission is difficult because emission of these gases from rice fields are depend upon varieties of factors such as soil properties, rice varieties and agricultural practices. Methane emissions from rice fields appear to be decreased by field drainage and some important cultivation practices. In general field drainage has been preformed in order to protect the rice root from injury caused by extreme reduction conditions due to the decomposition of organic matter. 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.

This study focused on model implementation on methane emissions during field drainage in order to find out the accuracy estimation. The existing empirical model developed by Huang et al. 1998 [4] was chosen for estimate soil redox potential and methane emission in this study. The influence factors included soil redox potential, above ground biomass, % sand, soil temperature, and grain yield. But the important factor such as field drainage does not concerned in this model. The modification of previous model or develop a new model focus on field drainage need to study.

2 Hypothesis and method

Recent research has shown flooded soil provide a low redox potential (Eh) and methane is produced only after the Eh has been lowered to sufficiently negative values, typically less than -100 mV [5]. The critical soil Eh for initiation of methane production observed was approximately from -150 to -160 mV. Between -230 to -150 mV the relationship of methane production and soil Eh appeared to be negatively exponential [6].

The basic assumptions for this study are 1) changing of soil redox potential depend upon soil condition and drainage day, and 2) the relations between soil redox potential and methane production is linearity (based on the field experiment data from Sigren et. al. 1997 [7] and native field experiment at Samutsakorn province.

From previous research [4] the decline of soil Eh after flooding was described as the following equation.

$$Eh = 1390*t^{(-0.87)} - 250$$

Where Eh is soil and t is days after flooding (modified drain day was 3 to 20.6), the constant 250 represents the normal Eh in mV at the time flooding, and -0.87 is the empirical constant [4].

Above empirical model was applied in order to estimate methane emission during flooded period. In addition the relation between Eh and methane emission during draining period was considered. Base on assumptions and data from native rice field observation; the relation between drain day and soil Eh in the draining period was described as:

$$Eh = A(L) + B$$

Where Eh is soil redox potential, A is decreasing rate of Eh per day in mV, L is draining days, and B is constant from fitting linear regression. We apply only the A(L) for Eh calculation because it is the decreasing rate that suitable for calculation and B is neglect.

Base on the data from native rice field observations, the decreasing rate of soil redox potential during drainage period was 7.3675 mV per day. The number of drain days and the decreasing rate of soil redox potential have been used as the supplements factor of the original model. The decline of soil Eh after draining was described as the following equation.

$$Eh = \{1390*t^{(-0.87)} - 250\} + \{A*L\}$$

This equation was applied when the field was drain. Where t is day after flooded and L is day after drain that start from 1 for the first drain day to the last drain day. The original model has been applied when the field was re-flooded. The day after flood (t) was calculated using soil redox potential value from the last drain day and original model.

3 Model validations

The data from a single rice-growing season in Texas, USA in 1991 and single rice-growing season in Samutsakorn province, THAILAND in 2002 without organic fertilizer application under different water management and rice varieties was used to validate the model. To estimate methane emissions during only flooded period we applied empirical model developed by Huang et al. 1998, and

modified model has been applied in order to estimate methane emission during draining period.

Texas Beaumont rice field is located in Jefferson County in the midst of the Texas-Louisiana rice belt. The soil used for this 1994 field experiment was classified as a thermic vertic ochraqualf (mollisil) and exhibits poor internal and surface drainage with percolation rates less than 0.5 mm/d after initial saturation. This soil is locally designated as Bernard-Morey and has a clay: sand: silt ratio of 27.3:33.3:39.4. The rice varieties were Mar, Lemont, and Labelle. Planted Mars, Lemont, and Labelle were planted using a seeding rate of 112 kg/ha. Row spacing was 20 cm apart. 56 kg N/ha as urea was applied just after planting. The field was received rain in the next day after planted and the permanent flooded were applied in the 42 days after planted [8].

The Samutsakorn field experiments lay out with four treatments in the wet season. Four different field drainages has been conducted: local method, continuously flooded, mid season drained, and multiple aeration. The Local method: normal flooded following the local irrigation practice. The continuously flooded: field was flooded since the 7 days after plant to 15 days before harvested. Midseason drainage: 6 days drain at 64 days after plant (flowering period). Multiple drainage: 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 25 kgN/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/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. Rice soil in this field experiment was Bangkok soil series and soil classified as Typic Tropaquepts.

4 Results

The results from model validation using field experiment from Texas Beaumont 1994 and Samutsakorn province shown in Table 1, Figure 1 and Figure 2.

Figure 1 shown predicted methane emissions and soil redox potential from Beaumont, Texas 1994. The yellow triangles shown methane emissions from field observations. Methane emissions were increased with increasing of flooded day, and decreased when the fields were drained. The red and blue squares shown predicted methane emissions and soil redox potential by existing empirical model [4] during flooded period and modified model has been applied during draining period. Predicted methane emissions were 40 and 4 % less than field

observation from Mars and Lemont varieties respectively. While predicted emission from Labelle varieties was 27 % higher than field observation.

As shown on Figure 2 has shown the yellow triangles shown methane emissions from field observations. Methane fluxes varied with water management, showing the highest seasonal emission from continuous flooding (35.81 g/m²) and the lowest from multiple aeration (16.91 g/m²), which more than 50 % lower than continuous flooded. The emissions rate from local method treatment (31.43 g/m²) and mid season drainage (18.76 g/m²) showed 18 and 48 % lower than continuously flooded fields. While the variation among field observations and predictions were less than ± 35 %. The highest predicted emissions from local method and the lowest predicted from mid season drainage. The red squares shown predicted methane emissions by existing empirical model [4] during flooded period and modified model has been applied during draining period. The purple circles and the blue squares represent soil redox potential from field observations and predictions. . Soil were decreased with increasing of flooded day, and increased when the fields were drained. The patterns of soil redox potential in flooded fields from filed observed and predicted were similar.

The model validations showed the model ability of confines patterns and amount of methane emissions. The predictions using modified model in this study can be reduced the gap of predictions by original model in most cased.

Table 1 the model validation using field experiment from Texas Beaumont 1994 and Samutsakorn 2003.

Sites	Treatments	Methane emissions (g/m ² /season)		
		Field observed	Original empirical model (Huang et al. 1998)	Modified model (this study)
Texas Beaumont USA 1994	Mars	33.50	17.36	20.36
	Lemont	22.00	16.91	21.22
	Labelle	14.42	17.29	18.36
Samutsakorn THAILAND 2002	Continuously flooded	35.81	36.94	24.20
	Local method	31.43	47.47	30.27
	Mid season drainage	18.76	35.26	19.87
	Multiple aerations	16.91	40.23	22.43

4 Discussions

To estimate methane emission from irrigation rice fields, model implementation is useful. However, the accuracy estimation depends on many influencing factors during cultivation period. Field drainage is one important factor influence on soil Eh and methane emission. On the basis of available information on rice cultivation, removing floodwater decreases methane emission because soil aeration inhibits methane production by methanogens. Therefore the modified model from this study is useful for define the emission during fields were drain. This modified model based on our basic assumption and we focused on draining period that effect on wet and dry conditions in rice soil. Only these important factor the modified model has been developed and it can well confined the patterns and amount of methane emissions from irrigation rice field. However, other factor such as soil pH, electro acceptors, and other factor in rice soil should be concern for more accuracy estimation.

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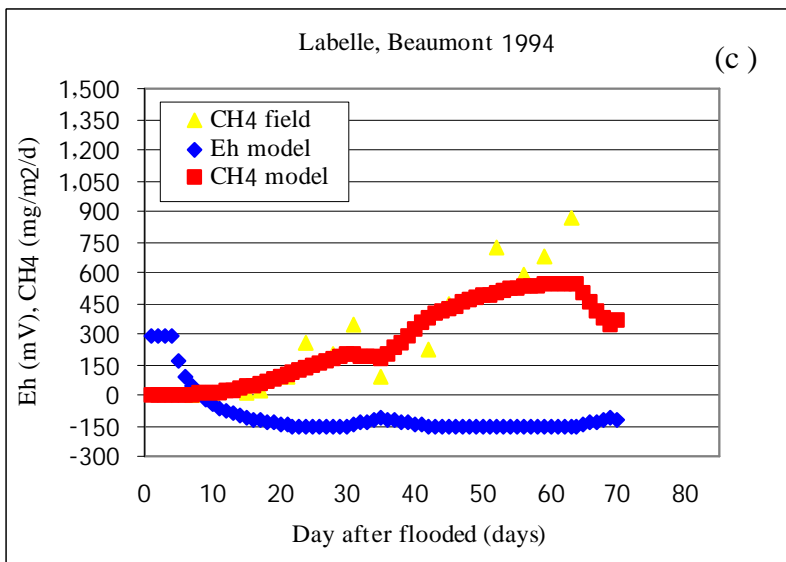
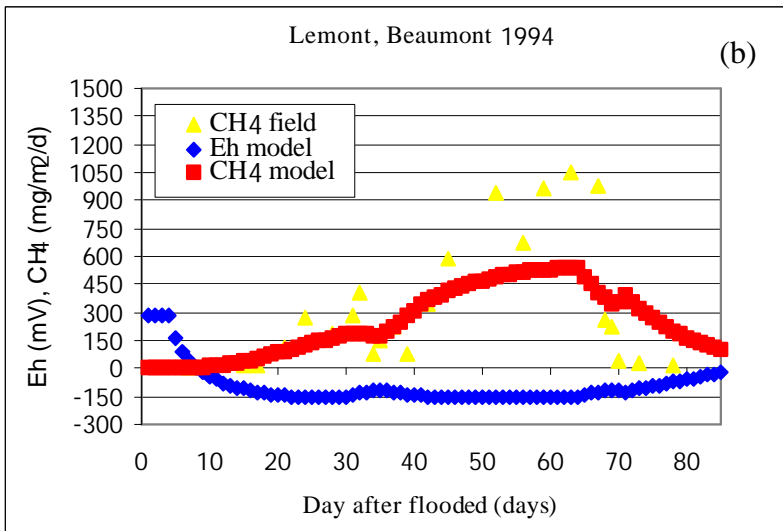
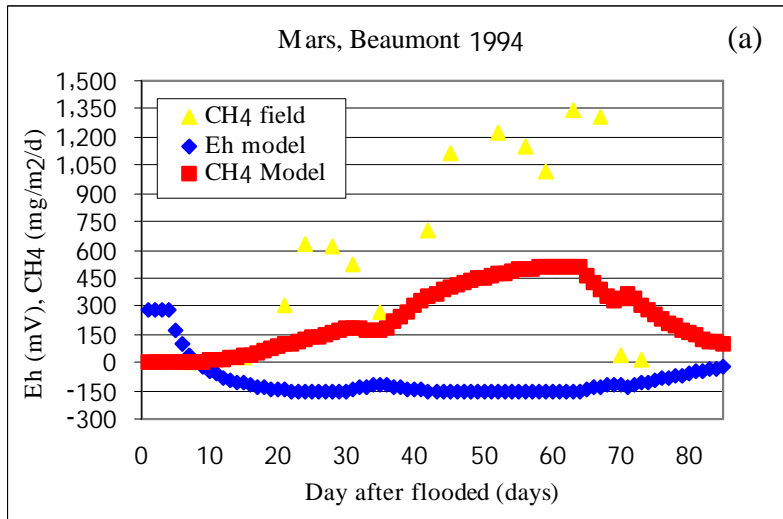


Figure 1: Measurements and predicted methane emissions from Beaumont, Texas 1994 (a) Mars variety, (b) Lemont variety, and (c) Labelle variety

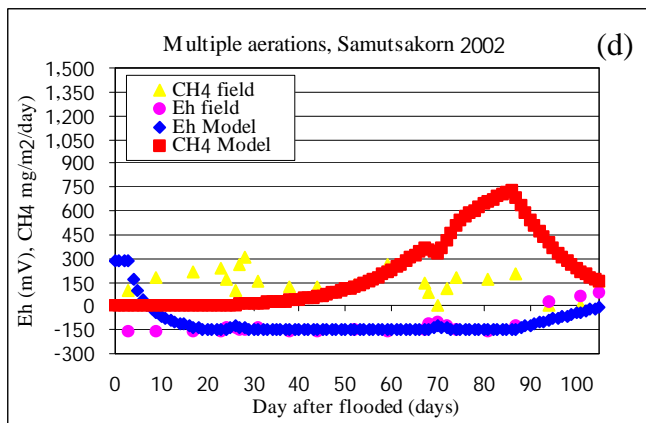
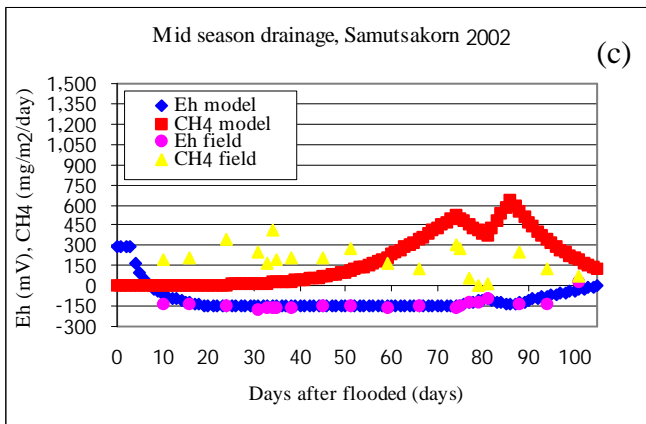
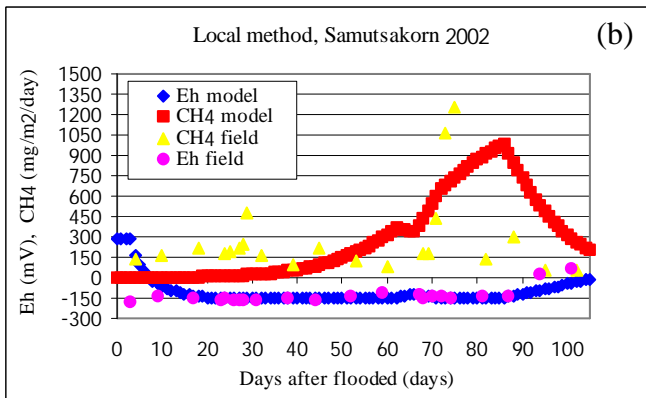
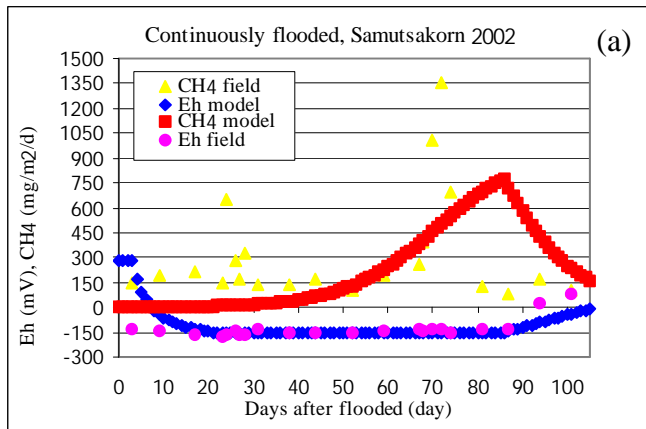


Figure 2: Measurements and predicted methane emissions from Samutsakorn province, Thailand 2002 (a) Continuously flooded, (b) Local method, (c) Mid season drainage, and (d) Multiple aerations