Methane (CH$_4$) Emission Flux Estimation in SRI (System of Rice Intensification) Method Rice Cultivation Using Different Varieties and Fertilization

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Abstract. The agricultural sector is one of the contributors of the greenhouse gases emission especially CO$_2$, CH$_4$ and N$_2$O. In its agricultural practice, rice paddy fields in Indonesia is cultivated twice to three times a year. Conventional rice planting method using water inundation and chemical fertilizer can result in the increase of greenhouse gases emission. One of those gases is methane (CH$_4$). Methane is formed through the decomposition of organic materials anaerobically in the rhizosphere with the help of methanogenic microbes. The release of methane can be influenced by several factors among them are the nature of the soil, irrigation system, fertilization and varieties used. The strategy to reduce emission conducted in this research are the usage of varieties that are considered to be low on methane emission such as Ciherang and IR64, rice paddy cultivation SRI (System of Rice Intensification) method using intermittent irrigation as well as fertilization. The setting of the intermittent irrigation uses IoT based (Internet of Thing) sensor technology for water level adjustment. The aim of this research is to analyze the methane flux produced from SRI method rice paddy cultivation based on the varieties used and different kinds of fertilization.

Keywords: CH$_4$; Paddy; SRI; GHG emission; Irrigation

1. Introduction

Agriculture is one of the main contributors to the greenhouse gas (GHG) emissions and it comprises of carbon dioxide (CO$_2$), methane (CH$_4$) and nitrous oxide (N$_2$O). One of the sources of the greenhouse gas emissions is from rice field cultivation. On the other hand, agricultural sector especially rice paddy is one of the main commodities in actualizing Indonesia’s food independence. This arises concern that it can increase the greenhouse gas emissions that can lead to climate change. There needs to be mitigation strategy to decrease the greenhouse gas emissions, one of them is by implementing SRI (System of Rice Intensification) that known to be an environmentally friendly and water saving rice paddy field cultivation method.

The land used for rice field contributes 11% CH$_4$ globally [1]. The rice plant has an important role in releasing methane (CH$_4$) to the atmosphere because it can increase the methanogenesis process through the release of root exudate that is rich in carbon sources. The root of the rice plant is able to exchange oxygen and it can form thermodynamic balance because 60-90% CH$_4$ produced by the rhizosphere layer...
through the aerenchyma vessels of the plant. The use of the rice paddy varieties can affect the greenhouse gas emissions and it is determined by the difference of the physiological and morphological properties from each of the varieties [2].

This research uses two varieties commonly used by rice paddy farmers in Indonesia and are known to be the varieties that are prone to climate change namely Ciherang and IR64 [3]. Another factor taken into consideration is the use of organic and inorganic fertilizer, wherein organic fertilization uses basic mature manure fertilizer and Local Microorganisms (MOL) whereas inorganic fertilization uses the addition of nitrogen fertilizer containing sulfur (ZA) or slow release fertilizer. The irrigation arrangements during rice paddy plant cultivation uses intermittent irrigation system. This is in lieu with the strategy to decrease CH₄ emissions by combining low-emissions technology components without decreasing paddy plant production. The aim of this research is to analyze methane (CH₄) flux produced by rice paddy cultivation using SRI method from varieties and different fertilizations during the vegetative phase.

2. Materials and Methods

2.1. Site and Experiment Description

This research was conducted at Kebun Tridharma, Faculty of Agriculture Universitas Gadjah Mada starting from October 2020, paddy cultivation uses box made from fiberglass measuring 150 x 100 x 40 cm as a growing media. Seeding is done on a small container (besek) filled with soil and manure fertilizer for 10 days and then it is moved to the growing media (soil and soil that has been mixed with mature manure fertilizer) in a fiberglass box that had been previously inundated for 2 days. Planting seeds done with the spacing of 30 cm x 30 cm and single cropping system (one hole for one plant). Irrigation arrangement based on the height and the water level kept at 0 cm, inundation done at the same time as seeding on the days after planting which are after the 10th, 20th, 30th and 40th day with the water level 2cm above the soil.

The design of the research uses physical model called Nested Design (Rancangan Tersarang). This research design consists of 2 factors which are fertilization and varieties. Fertilization factor (A) is diverse and varieties (B) do not have diversity but its diversity is located within factor A. Each factor consists of 2 levels and factor B is repeated 3 times.

Varieties
C : Ciherang
IR : IR64

Fertilization
P1 : manure fertilizer and MOL
P2 : manure fertilizer, ZA, SP36 and KCl

| Manure fertilizer and MOL (P1) | Manure fertilizer, ZA, SP36 and KCl (P2) |
|-------------------------------|------------------------------------------|
| C    IR     IR     C    IR2    C    IR    C1    C    C    IR3    IR |
| C1   IR     IR     C    IR     C    C    C    IR     C    C    IR    |
| C    IR1    IR     IR    C    IR    IR1   IR    C    IR    IR    IR |
| IR   C      C2    C    C     C    IR    C2    C    C     IR    |
| IR   IR     IR     C3    C    IR3   C    IR    C    IR2   IR    C3 |

Table 1. Plot of the experiment design
### Table 2. Fertilization treatment dosage (P1)

| DAT (0) | Manure fertilizer (kg) | MOL (ml) | Ratio |
|---------|------------------------|----------|-------|
| 0       | 3                      | 6        | 1 : 10|
| 10      |                        | 6        | 1 : 8 |
| 20      |                        | 6        | 1 : 6 |
| 30      |                        | 6        | 1 : 5 |
| 40      |                        | 6        |       |

Table description: Manure fertilizer = 2 kg/m² and MOL = 4 ml/m²

### Table 3. Fertilization treatment dosage (P2)

| DAT (0) | Manure fertilizer (gram) | ZA (gram) | SP36 (gram) | KCl (gram) |
|---------|--------------------------|-----------|-------------|------------|
| 0       | 3000                     | 11.25     | 15          | 7.5        |
| 10      |                          | 11.25     | 15          | 7.5        |
| 25      |                          | 22.5      | 15          | 7.5        |
| 40      |                          | 11.25     | 15          | 7.5        |

Table description: ZA = 30 g/m², SP36 = 10 g/m², and KCl = 10 g/m²

### 2.2. Measurement and Data Analysis

#### 2.2.1 Climate and Soil
Weather measurements comprise of rainfall, solar radiation, temperature and humidity using Davis weather channel equipped with Decagon EM50 data logger. Soil data comprises of the temperature of the soil, humidity and Electrical Conductivity (EC) using 5-TE sensor.

#### 2.2.2 CH4 emissions
Methane gas sampling was conducted during the vegetative phase. The chamber has been equipped with thermometer, injector, fan, and plastic bag are placed inside. The fan is then turned on and the gas samples are taken using the injector equipped with rubber tube and 3 way faucet connected to the chamber. The gas sample then put inside a plain vacuum tube and sealed with nail polish. The sampling of the gas is conducted three times from minute 0 until minute 20.

![Figure 1. CH4 collection scheme using chamber](image-url)
The result of the methane analysis using Gas Chromatography (GC) is in the form of ppm unit value. To determine the methane emission flux according to the rate of change in the concentration of the gas per unit time this equation is used [4]:

$$E = \frac{\delta C}{\delta t} \times h_{ch} \times \frac{mW}{mV} \times \frac{273.2}{273.2 + T}$$

(1)

Where, $E$ is flux CH$_4$ (mg/m$^2$/minute), $\frac{\delta C}{\delta t}$ is the difference of CH$_4$ concentration per collection time, (ppm/minute), $h_{ch}$ is the height of the chamber (cm), $mW$ is molecular weight CH$_4$ (g), $mV$ is molecular volume CH$_4$ (22.41 liter at standard temperature and pressure), and $T$ is temperature during sampling ($^\circ$C).

2.2.3 Plant height and Tillers
The height and tiller of the rice plant during the vegetative phase measured every 5 days.

3. Result and Discussion

3.1. Climate and Soil

| Table 4. Climate Data during the Research Period |
|-----------------------------------------------|
| Temperature ($^\circ$C) | Humidity (%) | Solar Radiation (W/m$^2$) | Precipitation (mm) |
|-------------------------|--------------|---------------------------|---------------------|
| Min                     | 22.2         | 44                        | 7.3                 |
| Average                 | 27.79        | 78.5                      | 169 Total 350       |
| Max                     | 38.3         | 94.6                      | 922.3               |

Based on Table 4, some climate data at the study location shows that the average air temperature is 27.79$^\circ$C with 78.5% humidity and 169 W/m$^2$ irradiation. Meanwhile, the total rainfall during the research period in the vegetative phase was 350mm.

| Table 5. Soil Data on Cage Fertilization Treatment and MOL during the Research Period |
|-----------------------------------------------|
| P1                                           |
| Temperature ($^\circ$C) | Humidity m$^3$/m$^3$ | EC (mS/cm) | pH |
|-------------------------|-----------------------|------------|----|
| Min                     | 25.20                 | 0.30       | 0.16|
| Average                 | 29.14                 | 0.34       | 0.38| 7.48|
| Max                     | 34.40                 | 0.39       | 0.59|

| Table 6. Soil Data on Cage Fertilization Treatment, ZA, SP36 and KCl during the Research Period |
|-----------------------------------------------|
| P2                                           |
| Temperature ($^\circ$C) | Humidity m$^3$/m$^3$ | EC (mS/cm) | pH |
|-------------------------|-----------------------|------------|----|
| Min                     | 25.30                 | 0.33       | 0.42|
| Average                 | 29.06                 | 0.37       | 0.55| 7.44|
| Max                     | 34.30                 | 0.46       | 0.63|

The results of measurements of soil temperature, soil moisture, Electrical Conductivity, and soil pH from the two treatments, namely P1 and P2 in Table 5 and Table 6, show that the average values are not much different. This measurement intends to see the relationship between the microenvironment and the CH$_4$ gas flux, where soil temperature plays a significant role in the activity of soil microorganisms. It is known that most of the methanogenic bacteria formed at an optimum temperature between 30-40$^\circ$C. The results of this study are to indicate the average soil temperature of both P1 and P2 treatments in the
range of 29°C. Besides, the maximum CH₄ formation occurs at a soil pH of 6.9-7.1. At a pH below 5.75 or above 8.75, CH₄ formation inhibited [5]. The pH measurement in this study from the two treatments had an average value of 7.4.

3.2. Flux Methane (CH₄)

| Treatment | E (mg/m²/day) |
|-----------|--------------|
| P1-C      | -22.68       |
| P1-IR     | -132.72      |
| P2-C      | 601.80       |
| P2-IR     | -77.58       |

Based on the CH₄ gas data obtained in the vegetative phase, it shows that the flux of CH₄ gas emissions in the fertilizer treatment between manure, ZA, SP36, and KCl with Ciherang varieties is 601.80 mg/m²/day. Meanwhile, in the same fertilization treatment with the IR64 type, the flux value was negative. Likewise, with the fertilization treatment between cages and MOL on both varieties, namely Ciherang and IR64, the CH₄ gas emission flux was negative. It can occur because of the absorption of CH₄ gas in rice fields. The structure of rice fields consisting of aerobic and anaerobic areas is an environment for producing and oxidizing CH₄ gas by the activity of microorganisms. The absorption mechanism is occurred by the oxidation reaction of CH₄ gas and happened in aerobic areas with the help of Methane oxidizing bacteria (MOB) that use CH₄ as a source of carbon and energy for growth. The CH₄ oxidation reaction requires O₂ only at the beginning of the response. This oxidation reaction produces CO₂ that is released into the atmosphere.

3.3. Plant Height and Number of Tillers

3.3.1 Plant height

The data on the measurement of plant height against time (plant age) plots into a graph, and the results are as shown in the following Figure 2.

![Figure 2](image)
Figure 2. shows that the height of rice plants in the vegetative phase increases rapidly with time. Based on the two treatments, it seems that the rice with the cage fertilization treatment, ZA, SP36, and KCl from the two varieties named Ciherang and IR64, gave a good response and was higher than the fertilization treatment with occasional and MOL.

3.3.2 Tillers
The data for calculating the number of tillers against time (plant age) plots on a graph, and the results are as shown in the following Figure 3.

Based on Figure 3, it seems that the growth in the number of tillers increases rapidly as the rice ages. Fertilization treatment between manure, ZA, SP36, and KCl from the two varieties, namely Ciherang and IR64, gave a good response with a higher number of tillers than the occasional fertilization treatment and MOL of 23 Ciherang stems and IR64 with 26 stems, respectively. Meanwhile, the number of tillers in the manure and MOL treatment of the Ciherang variety was 14 stems and IR64 15 stems.

4. Conclusion
In the vegetative phase, it showed that the flux of CH₄ gas emissions in the fertilizer treatment between manure, ZA, SP36, and KCl with the Ciherang variety was 601.80 mg/m²/day. Meanwhile, in the same fertilization treatment with the IR64 type, the flux value was negative. Likewise, with the fertilization treatment between cages and MOL on both varieties, namely Ciherang and IR64, the CH₄ gas emission flux was negative.

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