# Greenhouse Gas Emissions in Long-Term Fertilization and Rice Varieties in Irrigated Rice Field

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**Abstract:** Food production needs to be increased by 70% to provide food in 2050. However, agricultural activities contribute to greenhouse gas (GHG) emissions of approximately 5% of national GHG emissions. The main greenhouse gas emissions from the agricultural sector are $CH_4$, which is 67% of total agricultural emissions, followed by $N_2O$ (30%) and $CO_2$ (3%). The development of food crops combined with livestock is one of the efficient carbon farming systems. An efficient carbon farming system is an agricultural system that optimally uses carbon contained in crop residues and livestock waste as a source of organic material. The system can provide added value to increase land and plant productivity, farmer income, energy efficiency, and reduce GHG emissions. The study was conducted to obtain GHG emissions ($CH_4$ and $N_2O$) on food crops to support carbon-efficient farming systems. This research was carried out at the Sukamandi Rice Center in the rainy season of 2013. Long-term fertilization treatments were observed in NPK fertilizer and Organic Material (OM) plots, while varieties were observed in Ciherang, Situ Bagendit, and Inpari 30. $CH_4$ and $N_2O$ emissions from each plot in 3 replications were taken four times (6 November 2013, 13 November 2013, 20 November 2013, and 27 November 2013). The results showed that OM treatment emitted $CH_4$ of 36.77 kg $CH_4$ ha-1season-1 was lower than NPK treatment, and NPK treatment emitted $N_2O$ by 0.68 kg $N_2O$ ha-1season-1 lower than OM treatment. For the treatment of Inpari 30 variety emitted of 27.73 kg, $CH_4$ ha-1season-1 lower than the Ciherang and Situ Bagendit variety while Situ Bagendit variety emitted N2O of 0.85 N2O ha-1season-1 lower than the Ciherang and Inpari variety. 30.Keywords: agriculture, biotechnology, sustainable.

**Keywords**: fertilizer; GHG; irrigated land; rice variety

## 1 Introduction

Agricultural activities contribute to greenhouse gas (GHG) emissions of approximately 5% of national GHG emissions. On the other hand, food production needs to be increased by 70% by increasing yields to provide food in 2050. The main greenhouse gas emissions from the agricultural sector are $CH_4$, which is 67% of total agricultural emissions, followed by $N_2O$ (30%) and $CO_2$ (3%) The total GHG emissions from the agricultural sector in 2000 were approximately 75,419.73 Gg $CO_2$-e. Between 2000 and 2005, agricultural GHG emissions increased by 6.3%. The main sources of emissions from this sector are wetland (69%) and livestock (28%) (SNC, 2009). Many mitigation efforts on CH4 emissions have been carried out, including through cultivation techniques and the use of low CH4 emission varieties. Based on the results of IAERI research, one model of rice cultivation that produces low GHG emissions is Integrated Crop Management in lowland rice (Setyanto, 2008),.

Result of global warming, the increase in Earth's temperatures a is predicted to reach 1-3.5oC by the end of 2100 (IPCC, 2007). As an illustration, an increase of 1.3 ppm of CH4 methane gas can increase atmospheric temperatures by 1 ° C (Neue, 1993). Annual global methane emissions are estimated to be 420-620 Tg/year, and the concentration increases by 1% to 1.7 ppmv (Wassmann et al., 2004). In 2011, the agricultural sector contributed to GHG emissions of 76,248 Gg CO2-e. Globally, the agricultural sector contributed to greenhouse gas emissions of 14% of total emissions in 2000 (Surmaini et al., 2015).

Methaneisthe final product of degradation of organic matter under anaerobic conditions. Most of the methane from the agricultural sector is produced from lowland (Carlsson-Kanyama & González, 2007). CH4 production is influenced by several soil parameters such as availability of inorganic elements, methanogen populations, groundwater, aeration, temperature, soil, pH, and salt (Mitra et al., 2012). Methane emissions are determined by differences in physiological and morphological properties of rice varieties. The ability of rice varieties to emitted methane depends on aerenchyma cavities, number of tillers, biomass, root patterns, metabolic activities (Surmaini et al., 2015), age, and root activity. Several varieties that have been studied produce low GHG emissions are IR 64, Dodokan, Tukad Balian, Batanghari, Ciherang, and Inpari 1 (Kartikawati et al., 2011).

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The development of a system of food crops and horticulture combined with livestock is one form of an efficient carbon farming system. An efficient carbon farming system is an agricultural system that optimally uses carbon contained in crop residues and livestock waste as a source of organic material. The system can provide added value in the form of increasing land and plant productivity, farmer income, energy efficiency, and reducing greenhouse gas emissions.

This study aims to obtain greenhouse gas emissions on food crops that support carbon-efficient farming systems.

## 2 Methods

CH4 and N2O emissions from each plot with 3 replications were taken four times every one week in November 2013. Manual sampling time intervals were 5', 10', 15', 20', and 25' since the chamber's top was closed. Long-term fertilization treatment was carried out on the plot NPK and Organic matter (OM). Varieties treatment was carried out on Ciherang, Situ Bagendit, and Inpari 30 plots.

Analysis of samples of greenhouse gases using the GHG 450 Variant brand gas chromatography with TCD, FID, and ECD detectors, carrier gas Ar, $N_2$, and He, and $H_2$ gas as FID fuel.

Examples of gas from the box are analyzed for the concentration of $CH_4$ and $N_2O$ gas using GHG with FID (Flame Ionization Detector) and TCD (Thermal Conductivity Detector) detectors. $CH_4/N_2O$ emissions are calculated using the formula from IAEA:

$$E = \frac{dc}{dt} \times \frac{Vch}{Ach} \times \frac{mW}{mV} \times \frac{273{,}2}{(273{,}2 + T)}$$

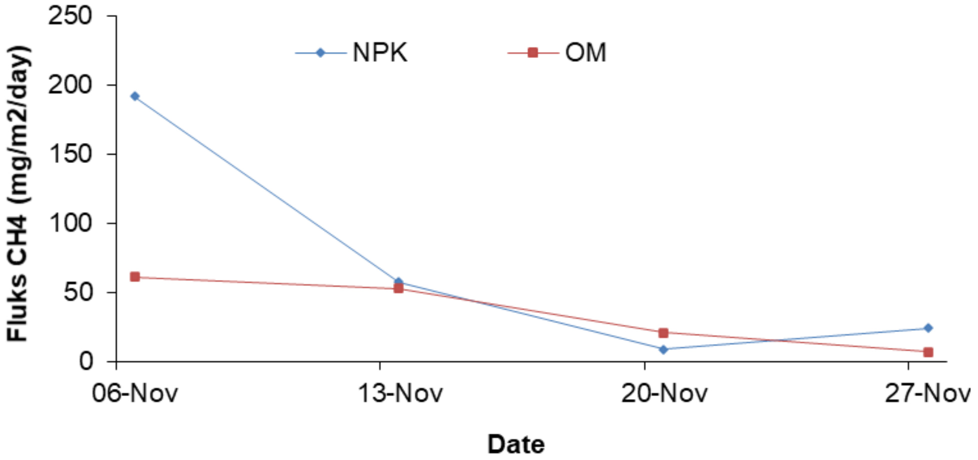
Where:
E : Flux CH4/N2O emissions (mg/m2/day)
dc/dt : CH4/N2O difference per time (ppm/minute)
Vch : Volume box (m3)
Ach : Area box (m2)
mW : Molecular weight (g)
mV : Molecular volume constans
T : Average temperature during sampling (°C)

Data in figure was presented as mean values standard deviations. The SAS 9.1.3 Portable analytical software package was used for all statistical analyses. Statistical analysis was accomplished by standard analysis of variance (ANOVA,) and the differences among treatments used Tukey test to determine significant differences.

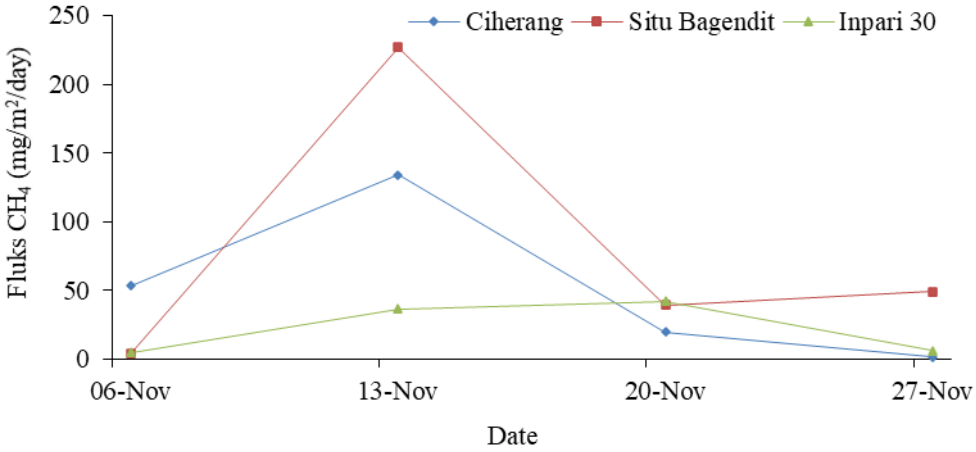
## 3 Result and Discussion

### 3.1 Fluks $CH_4$

The rice ecosystem with NPK fertilizer treatment produces a higher flux than OM, except in the third observation (Figure 1 (a)). The varieties used in the OM and NPK plots are Ciherang, Situ Bagendit, and Inpari 30. Daily $CH_4$ flux in NPK plots ranged from 6.68 to 357.54 mg $CH_4/m^2$/day, while plots were BO 0.91 to 103.75 mg $CH_4/m^2$/day (Figure1).



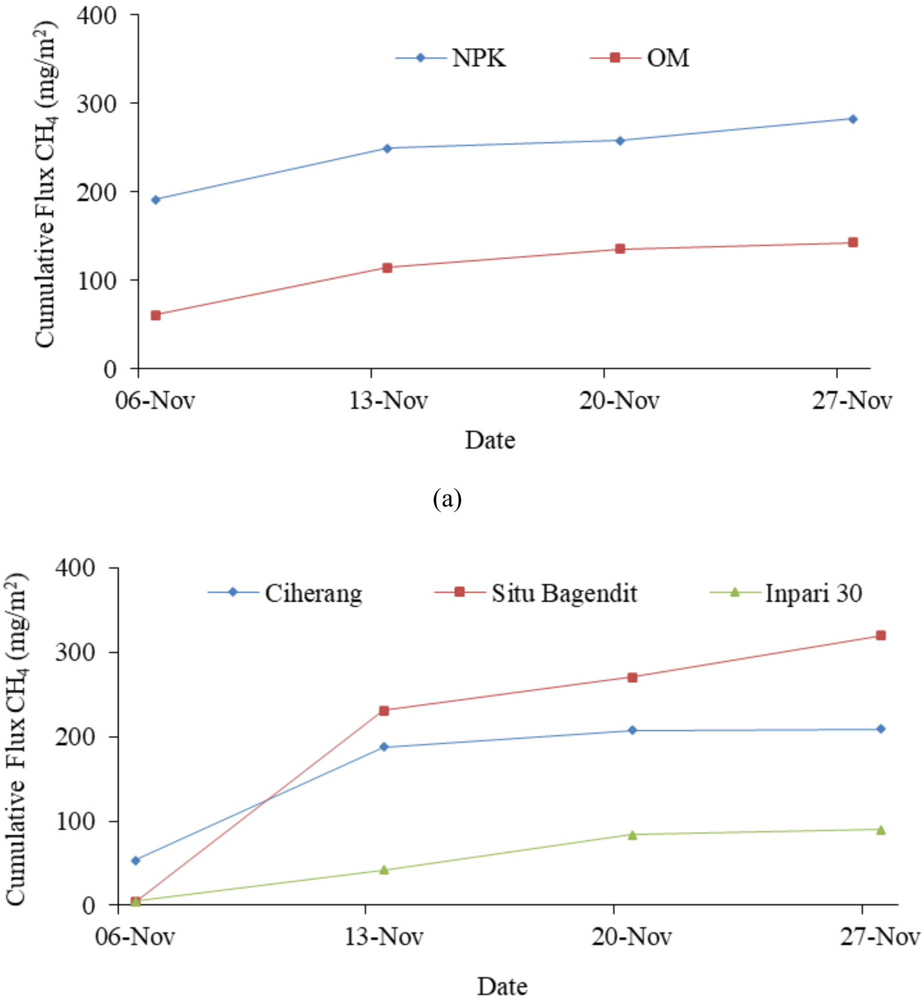
(a)



(b)

*Figure 1. CH4 flux in rice field with treatment (a) fertilizer and (b) different varieties*

Figure 1 (b) shows $CH_4$ flux of Ciherang, Situ Bagendit, and Inpari 30 varieties for four observations. In the second observation, the increase in flux that occurred in all varieties was suspected because rice plants had begun to be planted. The $CH_4$ flux of Ciherang ranged from 0.69 - 172.74 mg $CH_4$/m$^2$/day, Situ Bagendit 1.48 - 311.45 mg $CH_4$/m$^2$/day, and Inpari 30 2.48 - 63.01 mg $CH_4$/m$^2$/day.



(a)

(b)

*Figure 2. Cumulative CH4 flux in rice field with treatment (a) fertilizer and (b) different varieties*

The cumulative $CH_4$ flux in the NPK plot is higher than the OM plot. The NPK treatment produces 282.60 $CH_4/m^2$, while the OM treatment produces 142.78 $CH_4/m^2$ at the end of the observation. In the treatment of varieties, cumulative fluxes from the highest to the lowest were successively produced by the Situ Bagendit variety with a value of 319.73 mg $CH_4/m^2$, Ciherang 209.13 $CH_4/m^2$, and Inpari 30 30.05 $CH_4/m^2$ at the end observation (Figure 2 (b).

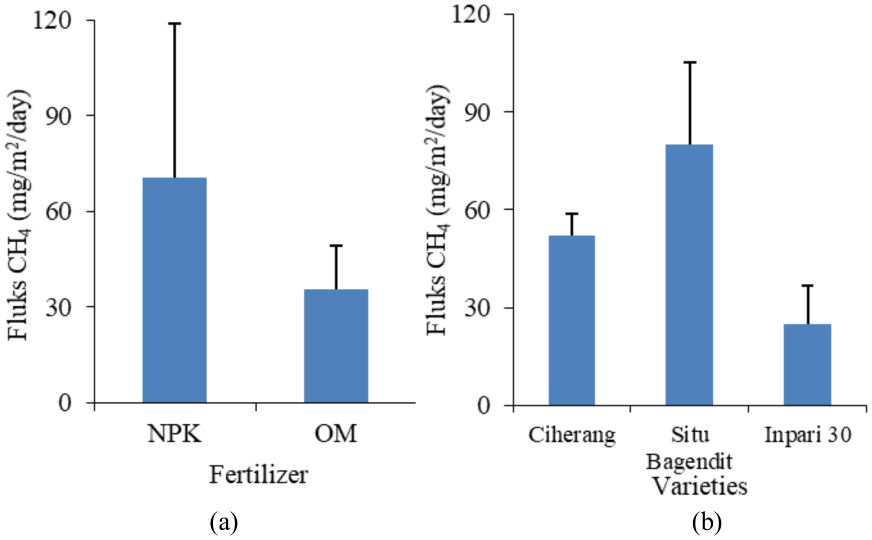


*Figure 3. The average CH4 flux of rice field in the treatment of (a) fertilizer and (b) rice varieties*

NPK fertilizer results in a higher $CH_4$ flux than OM (figure 3 (a). The average flux in NPK fertilizer is 70.65 mg $CH_4/m^2$/day, and OM fertilizer is 35.70 mg $CH_4/m^2$/day. Chirinda et al. (2010) argue that the use of organic fertilizer in the long term can increase soil carbon uptake, soil respiration, mineralized nitrogen potential, and ammonium oxidation potential. According to Aguilera et al. (2013), use an organic fertilizer is one of the ways to mitigate climate change through the absorption or sequestration of carbon, and to reduce the problem of waste management and the provision of soil nutrients.

While the user of inorganic fertilizers can accelerate the decomposition of organic residues and potentially reduce aggregate stability (Chirinda et al., 2010). In the previous study, the effect of inorganic fertilizer on $CH_4$ emissions still produced inconsistent data. Some studies say $CH_4$ emissions decrease with the addition of inorganic fertilizers, while other studies show an increase or no change. (Ma et al., 2013) reported that a decreased in $CH_4$ emissions by the addition of nitrogen fertilizer was due to the stimulation of methanotrophs on intermittent in lowland.

Situ Bagendit had the highest daily average groundwater level or standing water, which varied from 5.00-7.33 cm, followed by Ciherang 2.00-5.33 cm and Inpari 30 0.17-5.00 cm above ground level. The water level is thought to be a factor that influences CH4 flux in various treatments. In the inundated condition, the aerobic soil layer becomes less or the anaerobic soil layer becomes larger so that the methanogen microorganisms become more active and the $CH_4$ produced is difficult to oxidize (Liang et al., 2013).

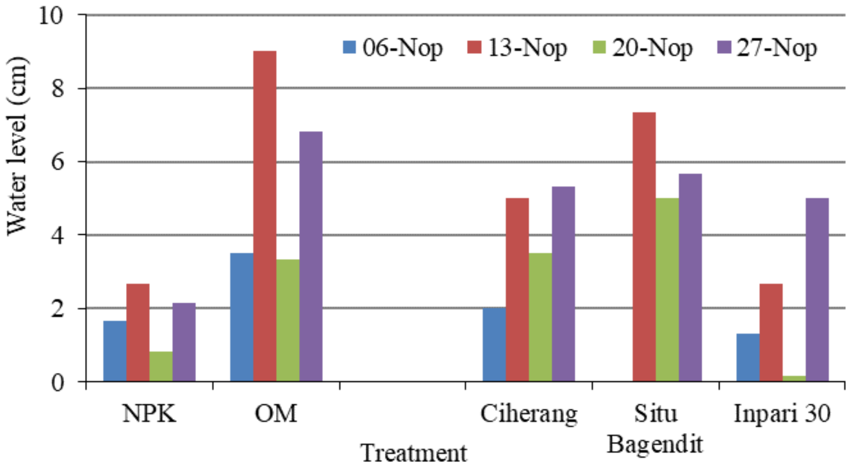
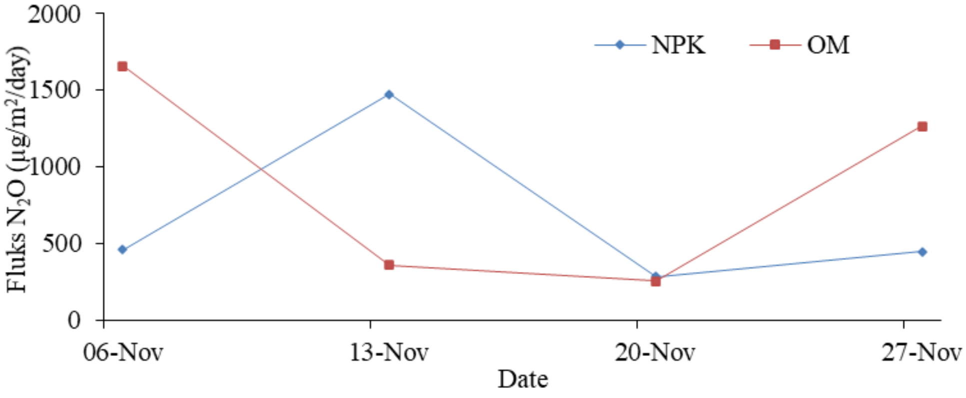


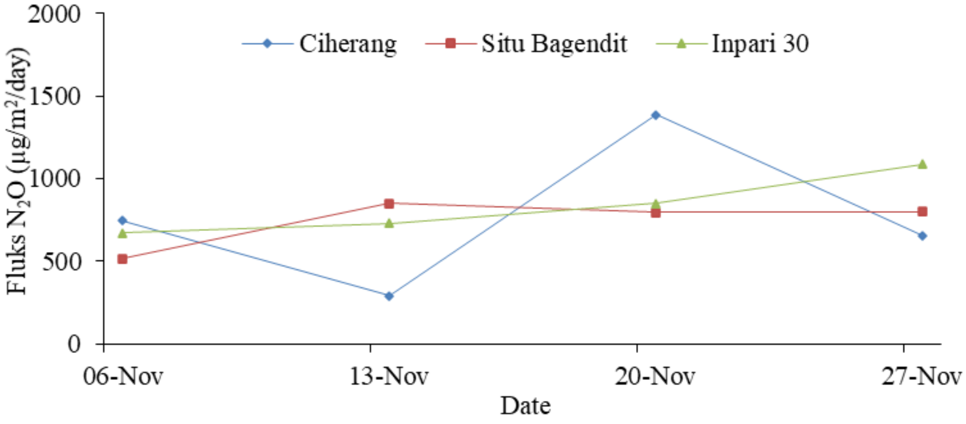
*Figure 4. Water level in a plot of observation of rice field GHG emissions*

According to Surmaini et al. (2015), the ability of rice varieties to emitted methane depends on aerenchyma cavity, number of tillers, biomass, root pattern, metabolic activity, age, and root activity. In this study, there are no supporting data for these parameters so that the influence of varieties on methane emissions can not be discussed further.

### *3.2 Fluks N2O*



(a)

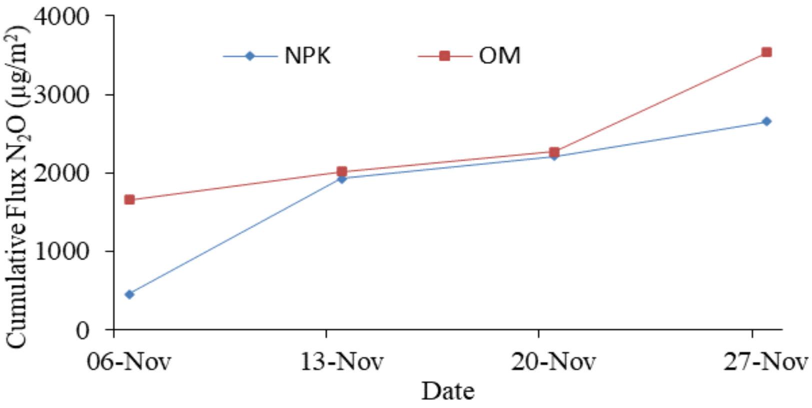


(b)

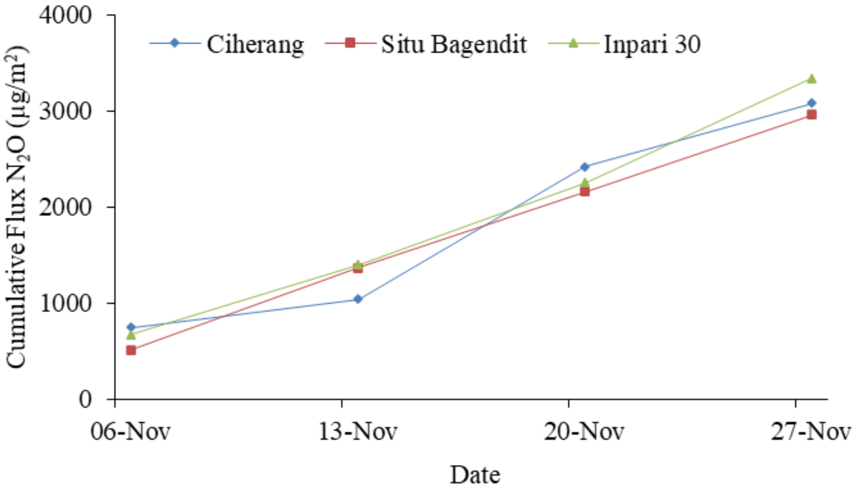
*Figure 5. N2O flux in the rice field with treatment (a) fertilizer and (b) different varieties*

$N_2O$ emissions increased in line with the aging of rice plants. Gogoi & Baruah (2012) reported that dissolved C-organisms in the rhizosphere of rice plants are influenced by root exudates, which increased along with plant growth. Besides, increased plant residues also cause an increase in dissolved organic C levels, followed by an increase in $N_2O$ emissions (Gogoi & Baruah, 2012).

NPK produced N2O flux ranging from 18.83 - 2835.43 µg N2O/m2/day. Whereas in the varieties, Ciherang produced 127.72 - 2680.07 µg N2O/m2/day, Situ Bagendit 64.50 - 1671.31 µg N2O/m2/day, and Inpari 30 226.78 - 2318.61 µg N2O/m2/day.



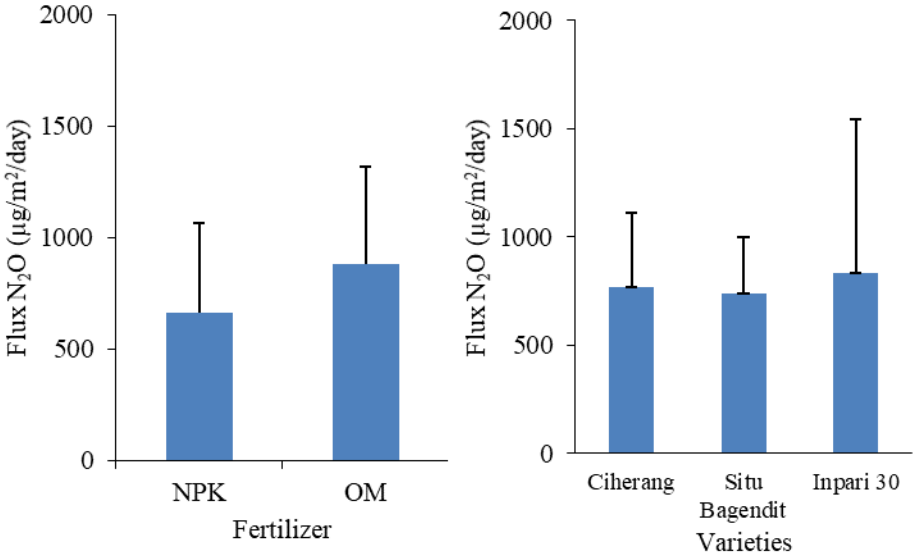
(a)



(b)

*Figure 6. N2O flux in the rice field with treatment (a) fertilizer and (b) different varieties*

The cumulative flux value of OM is higher than NPK, which is 3533.63 µg $N_2O/m^2$ and 2656.11 µg $N_2O/m^2$, respectively. Inpari 30 produced the highest cumulative flux of 3340.17 µg $N_2O/m^2$, then Ciherang 3082.18 µg $N_2O/m^2$, and the lowest was Situ Bagendit 2962.92 µg $N_2O/m^2$.



(a) (b)

*Figure 7. The average N2O flux of rice field in the treatment of (a) fertilizer and (b) rice varieties*

The treatment of OM resulted in higher $N_2O$ flux compared to NPK. The average value of $N_2O$ flux in OM was 883.41 µg $N_2O/m^2$/day, while NPK was 664.03 µg $N_2O/m^2$/day. Unlike the previous research, Chirinda et al. (2010) and Aguilera et al. (2013) examined $N_2O$ flux on agricultural soil by treating organic and synthetic fertilizers and produced higher cumulative values of N2O flux in soil with inorganic fertilizer compared to organic fertilizer. However, according to (Aguilera et al., 2013), the use of organic fertilizers in the long term can increased $N_2O$ emissions due to increased concentrations of soil organic matter and increased soil nitrogen levels due to the slow release of nitrogen minerals in organic fertilizers.

In contrast to the CH4 flux, the Inpari 30 variety produced the highest $N_2O$ flux value of 835.04 µg $N_2O/m^2$/day, followed by Ciherang 770.55 µg $N_2O/m^2$/day, and the lowest Situ Bagendit variety at 740.73 µg $N_2O/m^2$/day. Based on (Gogoi & Baruah, 2012) research, $N_2O$ flux in rice plants was also influenced by leaf area, canopy dry weight, and different root dry weight for each rice variety. In the study, the highest $N_2O$ emissions were produced by varieties that had leaf area, canopy dry weight, and highest root dry weight. This is because rice plants emit $N_2O$ via aerenchyma, and during the day, $N_2O$ transport from the roots to the canopy occurs through the transpiration channel then released through the stomata (Gogoi & Baruah, 2012). Research by (Gogoi & Baruah, 2012) on 17 plant taxa concluded that plant physiological characteristics can influence variations in $N_2O$ emissions.

Table 1: Total $CH_4$ and $N_2O$ Emissions in the Wetland Rice Ecosystem

| Treatment | | Emission total | |
|---|---|---|---|
| | | kg $CH_4$/ha/season | kg $N_2O$/ha/season |
| Fertilizer | NPK | 72.77 | 0.68 |
| | OM | 36.77 | 0.91 |
| Variety | Ciherang | 63.00 | 0.93 |
| | Situ Bagendit | 91.92 | 0.85 |
| | Inpari 30 | 27.73 | 0.93 |

While emissions of nitrous oxide are known to increase with the presence of soil fertilization activities, fertile soil is the key to sustainable commercialization on the scale of crop production for food, fodder and fiber crops. Only a small amount of agricultural land can be fertile without adding nutrients. Most of the soil is not fertile enough to require periodic and regular time with macronutrients such as Nitrogen (N), Phosphorus (P), Potassium (K), and other micronutrients needed by plants. Without the addition of nitrogen fertilizer, it is estimated that half the population of the current population cannot be supplied with enough food (Dawson & Hilton, 2011).

$N_2O$ emissions from agricultural land are mainly obtained from microbial activity, namely through nitrogen transformation in the form of nitrification and denitrification in the soil. Denitrification produces more $N_2O$ than nitrification, while nitrification produces more NO (Nitrogen Oxide). Nitrification occurs in an environment that is widely available in oxygen (oxic), while denitrification occurs in limited oxygen conditions (anoxic) (Smart et al., 2011).

The factors that have a major influence on $N_2O$ production are temperature, water (Chen et al., 2010), the amount of $NH_4$ + -N, and soil organic matter. The results of the study showed an increase in the amount of N administration, increasing $N_2O$ emissions (Meng et al., 2005; Setyanto, P., Mulyadi dan Zaini, 1997).

Increased natural (rain) and artificial soil (irrigation) moisture also resulted in rapid increases in $N_2O$ emissions and decreased efficiency of nitrogen uptake by plants (Allen, D., G. Kingstone, H. Rennerberg, R.C. Dalal, 2010).

Inundated soil conditions such as paddy fields and tidal land affect soil characteristics, biological activities, and the environment. Changes in soil characteristics due to oxidation-reduction processes result in a diversity of greenhouse gas fluxes (Unger et al., 2009). Therefore, the technology of rice farming can be sought to improve the efficiency of the use of agrochemicals, the preservation of natural resources, and the suppression of greenhouse gas emissions.

An efficient carbon farming system is an agricultural system that optimally utilizes the carbon contained in crop residues and livestock waste as a source of organic material that provides added value in the form of increased productivity, farmer income, energy efficiency, and reduced greenhouse gas emissions. Agricultural crop cultivation with integrated crop management approaches, livestock-crop integration, and low-input cultivation systems is a system of carbon-efficient farming.

The management of soil, water, and crops is the key to an efficient carbon farming system. According to Tisdale, Nelson, & Beaton (1993), organic materials function as plant nutrient reserves and supplies. Allen, Kingstone, Rennerberg, & Dalal, (2010) argue that increase cation exchange capacity, as an energy source for useful microbes for plants. Chen et al. (2010) argue that improve soil structure and capacity to hold groundwater, reduce soil compaction, and as a buffer against rapid changes in acidic, alkaline, or salinity reactions in the soil (Dawson & Hilton, 2011).

## 4. Conclusion

1. Organic matter emitted $CH_4$ smaller than NPK, whereas for $N_2O$ emissions, treat OM is greater than NPK.
2. Inpari 30 emitted the smallest $CH_4$ compared to the Ciherang and Situ Bagendit while the Bagendit situ emitted the smallest N2O compared to the Ciherang and Inpari 30.
3. The use of organic fertilizers is one of the ways to mitigate climate change.

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