EFFECTS OF WATER MANAGEMENT AND SOIL TYPE ON GREENHOUSE GASES EMISSION FROM RICE PRODUCTION IN AN GIA NG PROVINCE

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Abstract. Mekong delta has been well known for rice production of Viet Nam and had great contribution of rice export of Viet Nam and for acid sulfate and alluvial soils. Greenhouse gases emission from rice has been raised for its contribution to global warming. The technique of An Giang alternate wetting and drying (AAWD) has been recommended used for reduction of greenhouse gases. An experiment was set up with 3 factors of water management (AAWD and CF-continuous flooding), soil type (acid sulfate and alluvial soil) and seasonal effect (Spring Summer, Summer Autumn and Winter Spring) for collecting emission of CH₄, N₂O and rice yield. The CH₄ emission was less in the AAWD 2.76 mgCH₄.m⁻².h⁻¹ than in the CF 4.66 mgCH₄.m⁻².h⁻¹ (p < 0.05). Also, the rice yield was 5.87 ton.ha⁻¹.season⁻¹ for AAWD and higher than 4.80 ton.ha⁻¹.season⁻¹ for CF (p < 0.05). The soil type did not affect the greenhouse gases emission and the rice yield. The N₂O emission was very low and variation. The AAWD should be applied broadly to all the area of rice production in the Mekong delta due to its less greenhouse gases emission.

Keywords: CH₄, N₂O, rice production, alternate wetting and drying, continuous flooding, acid sulfate and alluvial soil.

Classification numbers: 3.4.5, 3.5.1, 3.8.3.

1. INTRODUCTION

Viet Nam is a country with an agricultural economy, rice production and exports which are the main livelihoods for more than 70% of the rural population [1]. According to the United...
Effects of water management, soil type on greenhouse gases emission from rice production

Nations Framework Convention on Climate Change (UNFCCC), agricultural production accounts for 33% of total GHG emissions, of which rice production was estimated to be 50% [2]. In the UNFCCC, Viet Nam expressed to reduce the Greenhouse Gas (GHG) emission from agriculture through sustainable agriculture developments. While the GHG emission from paddy farming (44.6 million-ton CO₂) accounts for approximately 18% of the emission from Viet Nam, paddy fields are expected to take important roles in reducing GHG. In recent years, the International Rice Research Institute (IRRI) and the Ministry of Agriculture and Rural Development in Viet Nam (MARD) have been disseminating An Giang alternate wetting and drying (AWD) technology in rice cultivation. AWD is a method of multiple aeration which was developed by the International Rice Research Institute and its partners to reduce the consumption of irrigation water [3]. In AWD, it is recommended to supply irrigation water when soil water potential at 5 cm below the soil surface reaches -10 to -30 kPa or when the surface water level declines to -5 cm below the soil surface [4, 5]. AWD application has been reported that it not only reduces water irrigation (23%) [6] but also has a potential of reducing GHG emission by 45-90% (CH₄, N₂O) [7] and increased 9-15% of the rice yield as well [8] compared to continuously flooding in the rice system. An Giang is a province located in upstream of the Mekong Delta, Viet Nam and has been pioneered in AWD disseminating which applied areas accounted for 52.1% in 2017 [9] in which Chau Thanh, Thoai Son, Cho Moi and Tri Ton were the four districts with the largest area of rice cultivation, contributing to An Giang’s rice production and reduce greenhouse gas emission. The study aims (i) to establish the baseline GHG emission from paddy field and (ii) to investigate the effects of water management regime to CH₄, N₂O emission from paddy fields in An Giang province.

2. MATERIALS AND METHODS

2.1. Experiment design

The study was conducted within 2 years from 01/2016 – 12/2017 with triple cropping (Winter-Spring, Spring-Summer, Summer-Autumn) paddy fields in Cho Moi, Chau Thanh, Thoai Son and Tri Ton districts. The rice variety of four districts were IR50404 and OM5451 with the growth stage from 85 – 90 days after sowing.

| Treatment | District  | Soil type  | Target water level (cm) | Area (ha) | Water management                                      |
|-----------|-----------|------------|-------------------------|-----------|-------------------------------------------------------|
| CF        | Cho Moi   | Alluvial   | + 5 cm                  | 0.25      | Water level was kept standing 2-5 cm from soil surface|
|           | Chau Thanh| Alluvial   |                         | 0.45      |                                                       |
|           | Thoai Son | Acid sulfate |                        | 0.30      | Water was supplied when the water level reached down to -5 cm |
|           | Tri Ton   | Acid sulfate |                        | 0.60      |                                                       |
| AWD       | Cho Moi   | Alluvial   | ± 5 cm                  | 0.25      |                                                       |
|           | Chau Thanh| Alluvial   |                         | 0.60      |                                                       |
|           | Thoai Son | Acid sulfate |                        | 0.80      |                                                       |
|           | Tri Ton   | Acid sulfate |                        | 0.80      |                                                       |
The CF (continuous flooding) water level was maintained at +5 cm above the soil surface, while AAWD water level was controlled -5 cm to +5 cm compared with soil surface. The water levels in each field were recorded everyday during the experiment by water gauge. Perforated field water tubes were installed in the field to depths of 15 cm in every field to monitor the water level below the soil surface. In CF, standing water of 2 - 5 cm water depth was maintained from 10 DAT to 15 days before harvest. In the AAWD treatment, when the water disappeared in the tubes under -5 cm compare with the soil surface, the plot was irrigated again to a depth of around 5 cm above the soil surface. The selected paddy fields had the area in range of 0.25 - 0.8 ha (Table 1).

2.2 Sample collection and process

2.2.1 Soil sample

According to [10] found that the soil physico-chemical features at four districts were suitable for the growth of rice with the alluvial soil properties (Chau Thanh and Cho Moi district) showed that pH value reached 4.59 - 5.52, EC 0.11 - 0.17 mS/cm, organic matter 3.21 - 3.94 %, CEC 27.5 - 30.3 cmol.kg⁻¹ and soil texture included 56.8 – 61.7 % clay, 37.5 - 41.3 % silt, 0.82 - 1.91 % sand [11]. Whereas the acid sulfate soil characteristic at Thoai Son and Tri Ton district showed pH value fluctuated 4.55 - 5.93, EC 0.12 - 0.18 mS/cm, organic matter 3.21 - 3.52 %, CEC 25.1 - 33.3 cmol.kg⁻¹ and soil texture included 52.1 - 55.7 % clay, 43.1 - 46.7 % silt [12].

Soil samples collected before sowing and after harvest around 1 - 2 days and just collected once time during the experiment. The total samples taken 16 samples in experiment including CF and AWD treatments.

2.2.2. Methane and nitrous oxide samples

Closed chambers of 100 cm × 80 cm × 60 cm (height × width × length) were used for air sampling at 3 minute, 23rd minute after chamber setting and each air sample was injected to 10 mL vacuumed vials. The samples were collected weekly for 11 - 13 weeks from seedling to harvest.

CH₄ and N₂O were measured by gas chromatography (Shimadzu GC2014, Japan) and the emission rates were calculated as followed [13]:

\[ m(\text{CH}_4, t) = (M_c/22.4) \times V_{\text{height}}/100 \times S_t \times 3.600 \times (273/(273 + T)) \]

in which: \( m_{\text{CH}_4, t} \): emission rate (mgGHGs.m⁻².h⁻¹); \( M_c \): Mass of carbon molecular (12 g/mol); \( V_{\text{height}} \): height of chamber (cm), \( S_t \): approximate change of CH₄ concentration over time (ppm.s⁻¹) \( T \): the air temperature in the chamber (°C) [14].

\[ \text{Flux}_{\text{N}_2\text{O}} = \Delta C/\Delta T \times V/A \times \rho \times 273/(273+T) \times 28/44 \]

where \( \Delta C/\Delta T \) is the concentration change over time (ppb-N₂O h⁻¹); \( V \) is chamber volume (m³); \( A \) is chamber area (footprint; m²); \( \rho \) is gas density (1.977 kg m⁻³ for N₂O at 0 °C); and \( T \) is the mean air temperature inside the chamber (°C).

Water level were recorded manually from seedling stage to the day of harvest at 3 positions in each AAWD or CF.

2.2.3. Rice yield
Rice was harvested in 1 m² with 5 replicates. Seeds were separated for sunk grains with salt solution (87 g NaCl in 1 L tap water), dried at room temperature for a week and recorded the weight and moisture to adjust 14 % moisture as yield data.

2.3. Statistic processing method

The 3-way ANOVA was used to test the effects of soil type, water management and seasonal effects on CH₄, N₂O emission and rice yield by StatGraphics Centurion XV software (StatPoint, Warrenton, USA). The statistical significance was set at a p-value of less than 0.05.

3. RESULT AND DISCUSSION

3.1 Methane emission (CH₄)

Figure 1 showed the CH₄ emission of the three seasons had the same pattern and trend owing to the stages of rice growth. After 7 days of sowing, the emission rates were 6.45 - 6.93 mgCH₄.m⁻².h⁻¹ in Winter-Spring, 6.53 - 6.61 mgCH₄.m⁻².h⁻¹ in Spring-Summer and 5.69 - 10.3 mgCH₄.m⁻².h⁻¹ in Summer-Autumn. The emission rates increased to week 4 in the course of the rice cultivation. The CH₄ emission decreased to the values of 0.34 - 1.67 mgCH₄.m⁻².h⁻¹ in Winter-Spring, 1.62 - 1.75 mgCH₄.m⁻².h⁻¹ in Spring-Summer and 0.04 - 0.31 mgCH₄.m⁻².h⁻¹ in Summer-Autumn at the end of the course of rice cultivation. The CH₄ emission were found highest in the rice fields at the stages of after sowing, panicle initiation and flowering and to decrease at harvesting [15]. The CH₄ emission was highest in the rainy season summer-autumn due to difficulties of water management.
Figure 2. CH₄ emissions from rice fields of CF and AAWD.

Figure 2 showed the CF (4.66 mg CH₄.m⁻².h⁻¹) had the higher CH₄ emission than AAWD (2.76 mg CH₄.m⁻².h⁻¹) (p < 0.05) (Table 2) due to the soil of CF which was in less anaerobic conditions than AAWD, therefore CH₄ emissions of CF was higher than AAWD. These results were consistent with [16] showed that the implementation of AAWD reduced the seasonal CH₄ emission compared to CF. The results were agreed with [15] who found the CH₄ emission higher in soils with saturated than in non-saturated water.

Table 2. 3-way ANOVA of water management, soil types and seasonal effects on CH₄, N₂O and rice yields.

| Parameters | A    | B   | C   | AB  | AC  | BC  | ABC |
|-----------|------|-----|-----|-----|-----|-----|-----|
| CH₄       | 19.14*** | 0.09 | 2.78 | 0.0367* | 0.12 | 1.73 | 0.29 |
| N₂O       | 0.35  | 3.21 | 2.49 | 0.00 | 1.39 | 0.10 | 0.46 |
| Yield     | 16.09*** | 3.42 | 1.95 | 0.06 | 0.44 | 1.25 | 0.93 |

Note: A: AAWD and CF; B: Alluvial and acid soil; C: winter-spring; spring-summer and summer-autumn

3.2. Nitrous oxide emission (N₂O)

N₂O gases is usually the second targeted GHG after CH₄ and often occurs just after N fertilizer application and during drainage events in the rice-growing season [17]. Figure 3 and 4 showed that the emission of N₂O was not significant difference (p > 0.05) between three cropping season (Winter-Spring, Spring-Summer, and Summer-Autumn) and N₂O emissions increased at the time of fertilizer application and tend to increasing from the 8th week to harvest with the value of each season was showed in Figure 3.

Figure 3. N₂O emissions from rice fields of CF and AAWD.
The Winter-Spring (from -0.47 to 2.24 mgN\textsubscript{2}O.m\textsuperscript{-2}.h\textsuperscript{-1}), spring-summer (from -0.32 to 1.01 mgN\textsubscript{2}O.m\textsuperscript{-2}.h\textsuperscript{-1}), and Summer-Autumn (from -0.49 to 0.67 mgN\textsubscript{2}O.m\textsuperscript{-2}.h\textsuperscript{-1}).

Figure 4 showed the N\textsubscript{2}O gas emissions from AAWD were tended to be higher than CF, but the statistics results of two water management showed that N\textsubscript{2}O emission between CF and AAWD method was not significant difference (p > 0.05).

Cai et al. [18] found a strong inverse correlation between CH\textsubscript{4} and N\textsubscript{2}O, driven by the water regime – very little N\textsubscript{2}O emissions during field flooding, but rapidly increasing N\textsubscript{2}O emissions during drainage and many authors found that while AAWD has been shown reducing CH\textsubscript{4} emission by 48-93% [19, 20], it can result in increased N\textsubscript{2}O emissions, producing a trade-off between CH\textsubscript{4} and N\textsubscript{2}O emissions [21]. Figure 2 showed that the CH\textsubscript{4} emission of CF and AAWD in Winter-Spring decreased continuously from 8\textsuperscript{th} week to 12\textsuperscript{th} week with the value of CF (from 3.88 decreases to 1.67 mg.m\textsuperscript{-2}.h\textsuperscript{-1}) and AAWD (from 1.78 decreases to 0.34 mg.m\textsuperscript{-2}.h\textsuperscript{-1}), meanwhile N\textsubscript{2}O emission (Figure 3) increased dramatically in this period with the value of CF increases from 0.14 to 2.23 mg.m\textsuperscript{-2}.h\textsuperscript{-1} and N\textsubscript{2}O emission value of AAWD increases from 0.11 to 0.31 mg.m\textsuperscript{-2}.h\textsuperscript{-1}. The Spring-Summer and Summer-Autumn were tended to same with the Winter-Spring and this results also similar with many above authors. The N\textsubscript{2}O gas emissions from acid sulfate soil was higher than alluvial soil but not significantly difference (p > 0.05) with the average value of each types of soil was 1.08 ± 2.07 mgN\textsubscript{2}O.m\textsuperscript{-2}.h\textsuperscript{-1} and 1.01 ± 2.73 mgN\textsubscript{2}O.m\textsuperscript{-2}.h\textsuperscript{-1}, respectively.

### 3.3. Rice yield (ton/ha)

Figure 5 showed the yield had variation in range of 5.21-5.54 ton.ha\textsuperscript{-1} in the year round. The rice yields were 5.40 ± 0.3 ton.ha\textsuperscript{-1} and 5.27 ± 0.24 ton.ha\textsuperscript{-1} for the alluvial soil and acid sulfate soils. The CF had lower yield of 4.80 ± 0.29 ton.ha\textsuperscript{-1}.season\textsuperscript{-1} than that of the AAWD 5.87 ± 0.29 ton.ha\textsuperscript{-1}.season\textsuperscript{-1} (p < 0.05). AWD application increases rice yield which is due to reduce non-productive tillers, avoid lodging and enhance weather-resistance [22]. The results of [23] also showed that the similar trend with current research, the rice yield of AAWD treatment.
had 6.67 ton.ha\(^{-1}\) higher than CF 6.32 ton.ha\(^{-1}\) and the AAWD practices should be considered to apply in An Giang province.

![Figure 5](image_url)

*Figure 5. Rice yield of different water management, soil types and seasons.*

4. CONCLUSIONS

The study provides that the mean of CH\(_4\) emission of the AAWD irrigation was decreased by 49.2 \(\%\) (Winter-Spring), 41.2 \(\%\) (Spring-Summer), 31.3 \(\%\) (Summer-Autumn) compared to CF irrigation which was 3.04 mgCH\(_4\).m\(^2\).h\(^{-1}\), 3.91 mgCH\(_4\).m\(^2\).h\(^{-1}\), 5.45 mgCH\(_4\).m\(^2\).h\(^{-1}\), respectively, while there was no significant difference of CH\(_4\) emission between two kinds of soil comprising alluvial and acid sulfate soil. N\(_2\)O emission in the AAWD and CF paddy fields showed statistically non-significant difference by two water management regimes as well as soil types \(p > 0.05\). The yield of AAWD was higher than that of CF by 1.07 ton.ha\(^{-1}\) which corresponds to 22.3 \%. The AAWD with the current criteria reduced global warming potential of CH\(_4\), increased rice productivity and there was no negative effect by AAWD implementation was found in this study, confirming the feasibility of AAWD as a mitigation option for paddy GHG emission in Vietnam.

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