The horizons in soil profile will determine the magnitude of greenhouse gas production due to the difference of total organic carbon and other chemical properties. This study aimed to determine the potential production of methane (CH$_4$) and nitrous oxide (N$_2$O) in each horizon of soil profile from organic and conventional rice fields. Soil samples which were taken from Imogiri Bantul D.I. Yogyakarta, were used to determine soil properties, the potential of CH$_4$ and N$_2$O productions. The correlation analysis was used to determine the relationship between production of CH$_4$ and N$_2$O with soil properties. The results showed that production of CH$_4$ and N$_2$O will be decreased with the increase of soil depth. Production of CH$_4$ and N$_2$O was higher in organic rice field than in conventional rice field. The total organic carbon (TOC) correlated positively with CH$_4$-production ($r=0.89$, $P<0.001$, $n=8$) and N$_2$O-production ($r=0.87$, $P<0.001$, $n=8$). The nitrogen content also correlated positively with CH$_4$-production ($r=0.87$, $P<0.001$, $n=8$) and N$_2$O-production ($r=0.94$, $P<0.001$, $n=8$). Mitigation of CH$_4$ and N$_2$O emissions should consider of C and N in the soil.

**Keywords:** CH$_4$, N$_2$O, profile, soil, emission


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**INTRODUCTION**

Rice fields are considered to be an important source of greenhouse gas emission especially CH$_4$ and N$_2$O (Mosier, Wassmann, Verchot, King, & Palm, 2004). Greenhouse gas emissions from rice fields are mainly influenced by the practices of rice cultivation (Smith et al., 2007). Drainage prevents the occurrence of strong anaerobic conditions in the soil and can reduce emissions of CH$_4$ (Cai et al., 1997; Zou, Huang, Jiang, Zheng, & Sass, 2005), but leads to nitrification-denitrification and significantly produces N$_2$O (Diba, Shimizu, & Hatano, 2011).

Organic carbon plays an important role in maintaining soil fertility, soil health and crop production (Thangarajan, Bolan, Tian, Naidu, & Kunhikrishnan, 2013). However, improper organic material or management used may encourage the increase of greenhouse gas emissions into the atmosphere. CH$_4$ is produced in flooded soils by methanogen (Le Mer & Roger, 2001), with organic matter as substrate (Hou et al., 2013; Zou et al., 2005).
N₂O is produced by nitrification-denitrification from agricultural soil management (Lal, 2007).

Organic farming has been utilized to improve the environment and make agriculture sustainable (Sutanto, 2002). In the organic rice fields, like in Jayan, Kebonagung, Imogiri, Bantul, D.I. Yogyakarta, the farmer usually uses in various doses of organic fertilizers, about 5-10 tons ha⁻¹ planting season⁻¹. In the conventional rice fields, the farmer usually uses chemical fertilizer urea and phosnska; 100-150 and 250-300 kg ha⁻¹ planting season⁻¹, respectively. Because of the use of organic fertilizer, CH₄ emission from organic rice field higher than conventional rice field (Aguilera, Guzmán, & Alonso, 2014; Qin, Liu, Guo, Liu, & Zou, 2010), N₂O emission too (Qin et al., 2010). Organic C is a substrate for methanogens to produce CH₄ (Hou et al., 2013; Zou et al., 2005), more available in organic rice fields. Organic C is a substrate for denitrification (Vilain, Garnier, Decuq, & Lugnot, 2014), so N₂O production higher from the organic rice field.

The production of greenhouse gases on each horizon in the soil profile will determine the amount of greenhouse gas emissions. This study aims to determine the potential of CH₄ and N₂O production in each horizon from the organic and conventional rice field. The results of the research can be used as consideration in mitigating CH₄ and N₂O emissions in the rice field, specifically the organic rice fields which produce more greenhouse gasses than conventional.

**MATERIALS AND METHOD**

**Soil profile**

The soil profile where was taken from organic and conventional rice fields was done in Jayan, Kebonagung, Imogiri, Bantul, D.I. Yogyakarta. Organic rice fields are usually given organic fertilizer with the doses 5-10 tons ha⁻¹ planting season⁻¹. Conventional rice fields are usually given chemical fertilizer phonska 250-300 kg ha⁻¹ planting season⁻¹ and urea 100-150 kg ha⁻¹ planting season⁻¹. Soil profile location of organic rice field at 7°56’01,22” N, 110°22’18,86” E and conventional rice field at 7°55’57,09” N, 110°22’17,05” E. Altitude 60 meter from sea level. The soil profile description was based on Soil Survey Staff (2014). The dimension of soil profile 1.5-meter width, 2.0-meter length, and 1.2-meter depth. Soil classified as Inceptisol. The soil samples were taken from each horizon then dried and sieved with 0.5 and 2 mm diameter-sieves.

**Soil properties**

Soil samples each horizon were analyzed which referred to Eviati & Sulaeman (2009), including C-organic (Walkley and Black method), N-total (Kjeldahl method), C humic acid-fulvate (extraction of sodium pyrophosphate + NaOH, H₂SO₄) and NO₃ soil (percolation, brucine method).

**Production of CH₄ and N₂O**

20 grams of soil samples with 0.5 mm diameter was dissolved in 40 ml of distilled water then incubated at 28 °C. Gas samples were taken with 5 ml syringe for laboratory analysis. Production of CH₄ and N₂O was analyzed by gas chromatography, for CH₄ with flame ionization detector (FID) and N₂O with electron capture detector (ECD). The potential production of CH₄ and N₂O was adopted using formula from Susilawati H.L. (2007), as follows:

\[
\text{CH}_4 - \text{N}_2\text{O Production} = \frac{(C24 - C0) \times Vhs \times MW \times Tsc}{WS \times Vm \times (Tsc + T)}
\]

where:

- \(C0\) = CH₄ - N₂O concentration at hour 0 (ppm)
- \(C24\) = CH₄ - N₂O concentration at hour 24 (ppm)
- \(Vhs\) = volume of headspace (ml)
WS = weight of soil sample (g)
MW = weight of molecule CH$_4$ – N$_2$O (g)
Vm = volume of CH$_4$–N$_2$O at standard conditions (273.2 K)
Tsc = temperature standard conditions (273.2 K)
T = air temperature of incubation (°C)

Statistical analysis
The correlation analysis was used to determine the relationship between potential production of CH$_4$ and N$_2$O with soil properties (Steel & Torrie, 1978).

RESULT AND DISCUSSIONS
Potential production of CH$_4$ dan N$_2$O
The soil profile from organic and conventional rice fields had four horizons (Apg, Bw1, Bw2, and Bw3). Table 1 shows the horizon, soil properties, CH$_4$-PP, and N$_2$O-PP. CH$_4$-PP and N$_2$O-PP in the organic rice field are higher than conventional ones. The production of CH$_4$ and N$_2$O will decrease with the increase of soil depth. CH$_4$-PP and N$_2$O-PP were associated with soil organic matter (TOC, HA, FA). Soil organic matter in organic rice field is higher than conventional, in topsoil is higher than subsoil.

Figure 1 and 2 shows that the CH$_4$ flux both in organic and conventional rice field has a similar pattern. The CH$_4$ flux increased and reached maximum on incubation at 15$^{th}$ day and after that subsequently decrease. The CH$_4$ flux in organic rice field was relatively higher than in conventional ones.

The surface soil (Apg) produced CH$_4$ higher than subsoil layer on incubation at 15$^{th}$ day. The higher total organic carbon (TOC) provides the more substrate for CH$_4$ formation. This result was in line with the study done by Brzezińska et al. (2012) and Mujiyo, Sunarminto, Hanudin, Widada, & Syamsiyah (2017) regarding the measurement of CH$_4$ production in logged condition. The soil with higher C-organic has more available substrates so it has higher and longer flux.

The flux pattern of N$_2$O differs between surface soil layer and subsoil layer (Figure 3 and 4). In the surface soil (Apg), the maximum N$_2$O flux was reached on incubation of 15$^{th}$ day. On the other hand, the N$_2$O flux in subsoil layers tends to decrease.

The relationship between the potential production of CH$_4$ and N$_2$O and soil properties
The potential production of CH$_4$ correlated positively with the total of organic carbon (TOC) (r=0.89, P<0.001, n=8), humic acid (HA) (r=0.71, P<0.005, n=8), fulvic acid (FA) (r=0.92, P<0.001, n=8), total nitrogen (TN) (r=0.87, P<0.001, n=8) and the ratio of total organic carbon-total nitrogen (TOC/TN) (r=0.65, P<0.005, n=8). Thus production of CH$_4$ is affected by soil organic matter. Study result of Aguilera et al. (2014) showed that the increase of CH$_4$ emissions in the organic rice system was associated with the addition of straw and manure to the soil. Application of rice straw will increase C-organic in soil which becomes a substrate for methanogenic bacteria (bacteria which produces CH$_4$) (Hou et al., 2013; Sass, Fisher, Hareombe, & Turner, 1991; Yagi & Minami, 1990), and consequences in increasing the production of CH$_4$ (Mujiyo, Sunarminto, Hanudin, Widada, & Syamsiyah, 2016; Swerts, Merckx, & Vlassak, 1996).

The C-organic in the upper horizon is higher than the lower horizon, as well as the production of CH$_4$ (Brzezińska et al., 2012; Mujiyo et al., 2017). The increase of C-organic is related to improve soil fertility and quality (Turmuktini et al., 2012) which will be maintained agricultural sustainability (Syamsiyah, Sunarminto, & Mujiyo, 2016). However, the increase in organic C also enhances methane formation so that appropriate management of organic matter is needed.
Table 1. Horizon, selected soil properties, CH₄-PP and N₂O-PP

<table>
<thead>
<tr>
<th>Profile</th>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Epipedon</th>
<th>Endopedon Classification</th>
<th>TOC</th>
<th>HA</th>
<th>FA</th>
<th>TN</th>
<th>NO₃⁻</th>
<th>CH₄-PP</th>
<th>N₂O-PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic</td>
<td>I(Apg)</td>
<td>0 – 24/26</td>
<td>Umbric</td>
<td></td>
<td>2.24</td>
<td>0.019</td>
<td>0.041</td>
<td>0.13</td>
<td>6.07</td>
<td>79.53</td>
<td>1.34</td>
</tr>
<tr>
<td></td>
<td>II(Bw1)</td>
<td>24/26 – 38/48</td>
<td>Cambic</td>
<td></td>
<td>1.08</td>
<td>0.017</td>
<td>0.023</td>
<td>0.10</td>
<td>8.73</td>
<td>60.31</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>III(Bw2)</td>
<td>38/48 – 70/80</td>
<td>Typic</td>
<td></td>
<td>0.98</td>
<td>0.016</td>
<td>0.016</td>
<td>0.08</td>
<td>8.17</td>
<td>56.03</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>IV(Bw3)</td>
<td>70/80 - 120</td>
<td>Humaquept</td>
<td></td>
<td>0.58</td>
<td>0.014</td>
<td>0.016</td>
<td>0.06</td>
<td>6.44</td>
<td>41.03</td>
<td>0.74</td>
</tr>
<tr>
<td>Conventional</td>
<td>I(Apg)</td>
<td>0 – 23/25</td>
<td>Umbric</td>
<td></td>
<td>1.18</td>
<td>0.021</td>
<td>0.025</td>
<td>0.12</td>
<td>7.27</td>
<td>59.36</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>II(Bw1)</td>
<td>23/25 – 47/54</td>
<td>Cambic</td>
<td></td>
<td>1.03</td>
<td>0.016</td>
<td>0.016</td>
<td>0.09</td>
<td>10.33</td>
<td>43.63</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>III(Bw2)</td>
<td>47/54 - 63/72</td>
<td>Typic</td>
<td></td>
<td>1.02</td>
<td>0.016</td>
<td>0.016</td>
<td>0.08</td>
<td>9.71</td>
<td>42.46</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>IV(Bw3)</td>
<td>63/72 – 120</td>
<td>Humaquept</td>
<td></td>
<td>0.72</td>
<td>0.010</td>
<td>0.015</td>
<td>0.07</td>
<td>9.41</td>
<td>37.40</td>
<td>0.68</td>
</tr>
</tbody>
</table>

TOC = total organic carbon; TN = total nitrogen; HA = humic acid; FA = fulvic acid; CH₄-PP = production potential of CH₄; N₂O-PP = production potential of N₂O

Potential production of N₂O correlated positively with total organic carbon (TOC) \( (r=0.87, \ P<0.001, \ n=8) \), humic acid (HA) \( (r=0.85, \ P<0.001, \ n=8) \), fulvic acid (FA) \( (r=0.82, \ P<0.001, \ n=8) \) and total nitrogen (TN) \( (r=0.94, \ P<0.001, \ n=8) \). This result was supported by finding of Qiu, Q., L. Wu, Z. Ouyang (2016) who stated that addition of N-organic fertilizer causes higher N₂O emissions than the application of single N-inorganic fertilizer or together with N-organic fertilizers. According to Huang, et al. (2004) application of organic matter produced higher N₂O emissions than urea. Pelster et al., 2012 specifically mentioned that application of organic matter in sandy loam soil will lead higher N₂O emissions than calcium ammonium nitrate fertilizer, but not in silty clay soil.
Organic rice field provides organic C higher than conventional rice field. In the microbial nitrification-denitrification process, bacteria use organic C as a denitrification substrate to produce N$_2$O (Vilain et al., 2014; Wagner-Riddle et al., 2007). While C-organic availability is suspected lead the higher mechanism of N$_2$O-PP in the organic rice field.

Potential production of N$_2$O will decrease with the increase of soil depth. This result is also supported by Vilain, Garnier, Roose-Amsaled, & Laville (2012) who stated that the production of N$_2$O in surface (upper) soil is higher than in the ground below.

The content of soil nitrate plays an important role for N$_2$O flux pattern in the surface soil and the soil below. Nitrates are intermediate products, which can be reduced to produce N$_2$O. The presence of nitrate will accelerate the formation of N$_2$O and the higher N$_2$O flux will occur. However, the maximum N$_2$O flux will not last long and soon decreased due to limited nitrate supply. There was a positive correlation between soil nitrate content and N$_2$O flux on day one ($r=84$, $P<0.001$, n=8) (Figure 5). These results were also supported by the studies from Burton, Zebarth, Gillam, & MacLeod (2008) and Engel, Liang, Wallander, & Bembeneq (2010) who stated that the nitrate content level was positively correlated with the level of N$_2$O emission.

CONCLUSION
The potential production of CH$_4$ and N$_2$O in soil is higher in the organic rice field than in the conventional rice field. The high production of CH$_4$ and N$_2$O is affected by the presence of organic matters and nitrogen in the soil. Potential production of CH$_4$ and N$_2$O in -what soil type- correlated positively with total organic carbon (TOC) and available nitrogen content. The presence of soil nitrate determines the N$_2$O flux pattern. The existence of C and N in the soil will be considered as mitigation action.

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