The effect of organic paddy field system to soil properties

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Abstract. This study aims to compare the soil properties among organic paddy field and other cultivation systems. Soil profile description was done to determine the soil horizons. The characteristics of organic paddy soil were better than others as it has C-organic in horizons I and II which were 2.09\% and 2.00\%, respectively; black soil color in horizon I (10 YR 2/1); microbial biomass C in horizon I and II which were 98.39 \(\mu\)g C/g soil and 418.01 \(\mu\)g C/g soil respectively; and microbial biomass N in horizon I and II which were 72.59 \(\mu\)g N/g soil and 59.11 \(\mu\)g N/g soil respectively. However, the unfavorable qualities of organic paddy soil including the clay leaching from horizon I (clay 24.56\%) to horizon II (clay 40.16\%) and high production potential of methane (\(\text{CH}_4\)) (1.81 \(\mu\)g CH\(_4\)/kg soil/day and 1.67 \(\mu\)g CH\(_4\)/kg soil/day, respectively in horizon I and II) need to be anticipated. The high amount of C-organic in organic paddy field affects the soil color was darker, and the increasing of clay leaching, microbial biomass C and N, and potential of \(\text{CH}_4\) production.

1. Introduction

Many studies investigated the good effects of organic paddy rice systems in soil properties. The organic paddy field is characterized by organic fertilizers exertion in each growing season. It has been widely reported that organic fertilizers significantly increase organic matter content in the soil. Benbi [1] stated that long-term applications of farmyard manure and rice straw resulted in a build-up of not only labile but also recalcitrant soil organic carbon pool. The presence of organic matter in the soil has an impact on the improvement of physical, chemical and biological properties of the soil.

But, until now, no study has predicted how the long-term disadvantage impact of organic farming systems on the soil properties. The long-term organic matter existence in the soil is related to the complex organic-clay formation, which affects to the mass mobilization and immobilization. The organic acids lead the improvement of clay fraction dispersion, so it is easily leached to the below horizon [2]. Some other studies indicate that the use of organic fertilizers in paddy field appears to increase the \(\text{CH}_4\) production. The series decomposition process of organic matter through the oxidation-reduction process will end with the formation of \(\text{CO}_2\) and \(\text{CH}_4\) [3, 4].

Over the last years, the effect of agricultural management practices on the soil properties and on crop yield has been widely studied in diverse types of agricultural soils [5]. Based on that problem, it is important to determine soil properties in paddy soils with diverse management practices. The objective of this study is to compare soil properties between organic paddy field and other cultivation systems, and also to find what the disadvantage impact to soil properties are in the organic paddy field.
2. Material and Methods
All site of soil profile samples were taken from paddy fields in Sukorejo Village, Sragen, Indonesia. The soil profiles are organic (P1), semi-organic (P2), conventional (P3) paddy field, and the teak forest land-use (P4) as a control. The criteria for organic paddy field selection is the use of organic fertilizers; for semi-organic is the use of chemical and organic fertilizers; for conventional is the use of most types of fertilizers (including both chemical and only occasionally organic fertilizers); and for the teak forest as a control is the land-use type of teak forest [6].

A soil profile is made at each site sampling with a size of width, length and depth; 1.5 m, 2.0 m and 1.5 m, respectively. The horizon was determined based on Soil Taxonomy USDA [7]. All observed soil and land character parameters were included on the boardlist with data and information referring to the Guidelines for Soil Description [8] and the Land Observation Technical Manual by Hidayat [9]. The soil texture and C-organic were analyzed based on Eviati and Sulaeman [10], soil colour were used Munsell Soil Color Charts [237], microbial biomass C dan N were determined based on Mueller [11], and CH₄ production potential was adopted from Susilowati [12] with the modification of adding acetylene as an inhibitor of methane oxidation [13, 14].

The differences soil properties between all paddy field systems were determined using one-way analysis of variance (ANOVA) with the Duncan’s Multiple Range test. The correlations between soil properties were determined using the correlation analysis [15] and the Pearson’s correlation coefficient was calculated as well. All statistical analysis were performed with SPSS Statistics 17.0 software.

3. Results and Discussion
The description of the soil profile shows that P1 and P2 consist of four horizons; P3 consists of five horizons; and P4 consists of six horizons. Table 1 shows horizon P1-P4 and selected soil properties.

There are some significant differences among the organic, semi-organic, conventional paddy field and the teak forest. In this paper is presented the diagnostic of soil properties that can distinguish among the soil samples, which is the content of C-organic, clay, colour, microbial biomass C and N, and methane production potential. The soil properties of C-organic, microbial biomass C and methane production potential have been explained by Mujiyo [6].

There was very significant difference in the content of C-organic between all soil profiles observed (one-way ANOVA F = 8.89, P < 0.01). C-organic on conventional paddy field was the lowest among the others because of the continuous rice cultivation without the using of organic fertilizer. This practice affected C-organic content is lower than its original soil (teak forests, as a control). Nakhro and Dkhar [16] stated the use of inorganic fertilizers in the paddy field resulted in low organic carbon content of the soil. Komatsuzaki and Syuabin [17] also stated that conventional farming leads the soil with lower soil carbon storage capacity than organic farming. Long term practice of organic paddy field with the use of organic fertilizer in each growing season became the primary factor that causes the organic paddy has higher amount of C-organic than the others.

Clay content on the horizon II in organic paddy field is the highest (40.16%). The long-term organic matter existence in the soil is related to complex organic-clay formation, which affects to mass mobilization and immobilization. Organic compounds interact with clay minerals on the external and internal surfaces through adsorption, and other mechanisms [18]. Organic acids improves clay fraction dispersion, so it is easily leached to the below horizon [2]. Dispersion of a clay particle from micro-aggregates are caused by adsorption of organic acid complex that increase negative charge of clay [19, 20], and it causes a certain clay particles release [2]. Finally, clay on horizon I was leaching and then was accumulating in the horizon II.

The significant differences occurred is the colour in horizon I at organic paddy field. It’s matrix colour was black (10 YR 2/1), which was the darkest among the others. It was caused by C-organic in the soil. The high value (dark colours) generally indicates high
content of C-organic in the soil [21]. C-organic had an important role in the correlation of Munsell colour value [22].

Table 1. Soil horizon of profile P1-P4 and selected soil properties

| Soil Profile | Horizon (Notation) | C-organic (%) [6] | Clay (%) | Colour (Hue Value/Chroma) | MBC (μg C/g soil) [6] | MBN (μg N/g soil) | CH4 PP (μg CH4/kg soil/day) |
|--------------|--------------------|-------------------|---------|--------------------------|----------------------|------------------|---------------------------|
| P1           | I (Ap)             | 2.09              | 24.56   | Black (10 YR 2/1)        | 498.39               | 72.59            | 1.81                      |
|              | II (Bt)            | 2.00              | 40.16   | Dark Yellowish Brown (10 YR 3/4) | 418.01               | 59.11            | 1.67                      |
|              | III (Bw1)          | 1.31              | 31.58   | Dark Yellowish Brown (10 YR 4/6) | 84.98                | 30.07            | 1.05                      |
|              | IV(Bw2)            | 1.30              | 37.62   | Yellowish Brown (10 YR 5/6) | 110.24               | 30.59            | 0.92                      |
| P2           | I (Ap)             | 1.78              | 29.63   | Dark Yellowish Brown (10 YR 3/4) | 475.42               | 59.37            | 1.23                      |
|              | II (Bw1)           | 1.65              | 28.07   | Yellowish Brown (10 YR 5/6) | 199.82               | 56.00            | 0.98                      |
|              | III (Bw2)          | 1.56              | 30.41   | Yellowish Brown (10 YR 5/6) | 172.26               | 38.89            | 0.82                      |
|              | IV (Bw3)           | 1.48              | 9.36    | Yellowish Brown (10 YR 5/6) | 321.54               | 33.70            | 0.66                      |
| P3           | I (Ap)             | 1.08              | 37.82   | Dark Yellowish Brown (10 YR 4/6) | 367.48               | 49.26            | 0.84                      |
|              | II (Bw1)           | 1.00              | 33.92   | Dark Yellowish Brown (10 YR 4/4) | 257.23               | 20.74            | 0.59                      |
|              | III (Bw2)          | 1.01              | 24.17   | Grayish Red (2.5 YR 5/2)  | 303.17               | 27.48            | 0.63                      |
|              | IV (Bw3)           | 0.68              | 33.14   | Reddish Brown (2.5 YR 4/6) | 261.83               | 27.22            | 0.66                      |
|              | V (Bw4)            | 0.78              | 26.90   | Reddish Brown (2.5 YR 5/3) | 266.42               | 16.33            | 0.53                      |
| P4           | I (Ap)             | 1.83              | 21.44   | Dark Brown (7.5 YR 3/3)   | 468.53               | 66.11            | 1.21                      |
|              | II (Bw1)           | 1.88              | 23.39   | Brown (7.5 YR 4/4)       | 443.27               | 57.04            | 1.12                      |
|              | III (Bw2)          | 1.63              | 26.12   | Bright Brown (7.5 YR 6/5) | 271.02               | 45.89            | 0.80                      |
|              | IV (Bw3)           | 1.52              | 28.07   | BrightBrown (7.5 YR 5/8)  | 282.50               | 36.30            | 0.67                      |
|              | V (Bw4)            | 1.35              | 15.79   | Bright Brown (7.5 YR 5/6) | 197.52               | 22.30            | 0.73                      |
|              | VI (Bw5)           | 1.24              | 22.22   | Orange (7.5 YR 6/8)      | 287.09               | 27.48            | 0.61                      |

P1 – organic; P2 – semi-organic; P3 – conventional paddy field; P4 – teak forest
Clay – relative percent with content of sand and silt to determine the soil texture, data not shown
MBC – microbial biomass C; MBN – microbial biomass N; CH4 PP – methane production potential

The microbial biomass C and N were describing the microbial population in the soil. The correlation between C-organic with microbial biomass C is significant (r = 0.52, P < 0.05, n = 19) [6], and with microbial biomass N is very significant (r = 0.84, P < 0.01, n = 19). Soil with high substrate of C-organic also has a high microbial population. C-organic in soil contains both living and non-living components. Living components consist of various soil microbial biomass [23]. Soil with high substrate of C-organic is able to support life and activity of different types of microbial metabolism with different types of morphology and physiology.

There was significant difference in methane production potential between all soil profile observed (one-way ANOVA F = 5.19, P < 0.01), which is on organic paddy field is the highest among the others. The most obvious soil properties which has close relationship with the CH4 production potential is the C-organic content (r = 0.80, P < 0.01, n = 19) [6]. The increasing content of C-organic soil will raise the CH4 production potential. Organic paddy soil has the highest average C-organic and CH4 production potential among other soils [6]. The soil has high amount of C-organic will be followed by the high amount of CH4 production [24, 25, 26]. Organic matter appears to increase the methane production [3, 4] by providing C sources and decreasing oxidation-reduction potential (Eh) [27, 28].

The CH4 production potential was also significantly correlated with microbial biomass C (r = 0.56, P < 0.05, n = 19) and N microbial biomass (r = 0.84, P < 0.01, n = 19). Microbial biomass C and N are significantly correlated with C-organic (r = 0.52, P < 0.05, n = 19; r = 0.84, P < 0.01, n = 19,
respectively). This correlation reinforces conjecture on soils containing high C-organic and microbial populations (including microbial methanogens forming CH$_4$) so also leads the high amount of the CH$_4$ production potential. The high amount of C-organic soil supports the development of methanogen populations to produce CH$_4$ from the reduction of CO$_2$ and H$_2$, CH$_3$OH and CH$_3$COOH [4, 29, 30].

4. Conclusion
The organic paddy system has led to better changes in soil properties. The long term practice of organic paddy field with the use of organic fertilizer in each growing season become the main factor that causes higher amounts of C-organic than semi-organic paddy field, conventional paddy field and teak forest. The soil in organic paddy field, especially in the horizon I, has highest of C-organic among the others, as the color of soil matrix in the horizon I was the darkest. The high amount of C-organic in organic paddy field affects the soil color was darker and also affects in the increasing of microbial biomass C and N. But, the unfavorable soil properties in the organic paddy field were clay leaching and high of methane production potential. The clay leaching from horizon I to horizon II needs to be anticipated as the clay is a key characteristic of soil fertility. The high production potential of methane also needs to be mitigated in order methane emissions from organic paddy field has to remain low.

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