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# Temporal variation in the soil properties and rice yield of organic rice farming in the tropical monsoon region, Indonesia

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**ABSTRACT**

One of the organic farming goals is improving soil properties to support sustainable rice production. This study investigated the soil properties and rice yields under temporal variation of organic rice fields. Soil sampling was conducted in organic rice fields with three temporal variations, namely 0, 4, 7, and 10 years in a tropical monsoon region in Central Java, Indonesia. Variables observed included soil organic carbon, soil carbon stock, soil microbes population, dissolved organic carbon, soil liquid limit, soil sticky limit, soil plasticity limit, soil color changing limit, soil friability, soil porosity, soil total nitrogen, soil total phosphorus, soil available sulfur, exchangeable calcium, cation exchange capacity, total potassium, bulk density, base saturation, exchangeable sodium, exchangeable potassium, and rice yield. This study confirms that soil organic carbon increased by 51.63% within 10 years (from 1.84% to 2.79%). Organic farming also improved all the physical, chemical, and biological soil properties, by the increase of soil organic carbon. However, soil organic carbon is mostly determined by soil cation exchange capacity, soil total phosphorus, and soil porosity. The mechanism of rice yield increase in organic rice farming is not affected by soil organic carbon directly but through the synergic increase in soil total nitrogen. The 1% increase of soil organic carbon increases 0.065% of soil total nitrogen hence rice yield increases by 1.66 tons ha$^{-1}$. This study supports sustainable agriculture by providing evidence of improved soil properties under organic farming.

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## 1. INTRODUCTION

Organic rice fields have been extending worldwide, including in Indonesia as a response to support organic farming. Organic rice fields support soil health to restore degraded wetlands for rice planting and provide healthy rice hence supporting a sustainable food system and security (Schreefel et al., 2020). Organic farming involves utilizing natural ingredients without using chemicals in practice hence environmentally friendly (Seufert, 2012) (Schoonbeek et al., 2013). Organic farming is also considered to conserve biodiversity, reduce greenhouse gas emissions, and improve energy efficiency (Reganold & Wachter, 2016; Seufert, 2012). Nowadays, organic farming has been applied by many farmers in Indonesia. Based on Organic Institute et al. (2019), the conversion of organic land for rice commodities has expanded yearly, in line with the increasing demand for organic rice.

Experimental fields that received manure applications showed higher microbial biomass and enzymatic reactions than those treated with chemical fertilizers and fields without fertilizer input (Chhogyel & Bajgai, 2016). Iqbal et al. (2022) found that manure application significantly increased soil organic C and biomass C. Also, three years after harvesting, soil organic carbon was found to be significantly higher in soils with the addition of green manure and vermicompost compared to chemical fertilizer fields (Singh et al., 2017). In addition, the application of organic fertilizer significantly increased the liquid limit and plastic index of soil compared to that without organic fertilizer application (Zong & Lu, 2020). Long-term use of chemical fertilizers in paddy field management has also been found to reduce soil organic carbon content and cause an increase in bulk density after flooding (Bi et al., 2015), in contrast to long-term conservation farming management systems result in vertical nutrient stratification, where nutrients are concentrated in the topsoil, affecting plant nutrient availability. Nutrient nitrogen is closely related to organic matter, and changes caused by conservation management by maintaining organic matter increase the N content in the soil (Jayaraman et al., 2021). In recent decades, chemical fertilizers have been used instead of organic fertilizers to increase crop yields (Zong & Lu, 2020). However, applying chemical fertilizers causes soil productivity degradation and increases the risk of water pollution (Bi et al., 2015; Blanco-Canqui et al., 2014; Naveed et al., 2014).

Arunrat et al. (2022) found that 4-years of organic rice farming in Thailand decreased greenhouse gas emissions by 3289.1 kg $CO_2eq.ha^{-1}.year^{-1}$ due to high carbon sequestration. Further, Pérez-Méndez et al. (2023) reported the long-term of organic farming (over 10 years) in northern Spain produced abundant communities of macroinvertebrate aquatic predators, hence the macroinvertebrate-mediated pest control was more efficient. In Bangladesh, green manuring rice fields with *Sesbania* for organic farming increased soil carbon storage up to 117% (Naher et al., 2019). To date, the studies regarding soil properties and rice yield of long-term (up to 10 years) of organic rice farming in tropical monsoon regions like Indonesia are very limited. Therefore, the objective of this study is to investigate the physical, chemical, and biological soil properties and the mechanism of rice yield improvement under 0, 4, 7 and 10 years of organic farming age.

## 2. MATERIAL AND METHODS

### 2.1. Sampling Stages

This research was carried out in rice fields with organic, semi-organic, and conventional management systems in Gentungan Village, Mojogedang, Karanganyar in Indonesia (7°32'40" - 7°32'58"S and 110°00'32" - 111°00'50"E) (Figure 1). Four (4) organic rice farming ages were investigated, including 0, 4, 7 and 10 years of organic farming ages. The management of organic rice fields was given 4.8 tons $ha^{-1}$ of manure during land preparation before starting the rice transplantation. The rice fields with 0 years of organic farming were managed by applying chemical fertilizers during early of vegetative phase (200 and 100 kg $ha^{-1}$ of urea and TSP, respectively) and early of reproduction phase (200 and 100 kg $ha^{-1}$ of Urea and ZA, respectively). Management of conventional rice fields was given 200 $kg.ha^{-1}$ of Urea and 100 $kg.ha^{-1}$ of TSP in the first stage and in the second stage 200 $kg.ha^{-1}$ of Urea and 100 $kg.ha^{-1}$ of ZA was applied.

The soil and plants were sampled during the harvest phase of rice plants at 5 (five) randomized points (representing five replications) at each organic rice farming age. Soil samples were taken at 0-20 cm depth using the boring method of both disturbed and undisturbed samples. Plant samples were taken using the 1 x 1 m tiling method.

### 2.2. Soil Analysis

Laboratory analysis of collected soil was carried out at the Laboratory of Physics and Soil Conservation and Laboratory of Chemistry and Soil Fertility at Sebelas Maret University. The parameters observed included total organic C measured using the Walkley and Black method by adding a 10% solution of 2 ml $K_2Cr_2O_7$ to 5 grams of soil then adding 5 ml of $H_2SO_4$ wait until it cools and add distilled water to the terra limit wait until the soil settles and detect colorimetric with a spectrophotometer (FAO, 2019), C microbes using fumigation and extraction-*chloroform* (Schinner et al., 2012) microbial C content is obtained by calculating the difference in organic C extracted by 0.5 M $K_2SO_4$ from fumigated soil and non-fumigated soil, bulk density using the sample ring method (Lestariningsih et al., 2013), and soil porosity calculated using the bulk density and particle density (Nkakini & Fubara-Manuel, 2012). Atterberg analysis includes the liquid limit, determined using the Casagrande method. Casagrande test procedure, it is the water content at which a pat of soil, cut by a standard-sized groove, will flow together for a distance of 13 mm under the impact of 25 blows in a standard cassagrande liquid limit device.

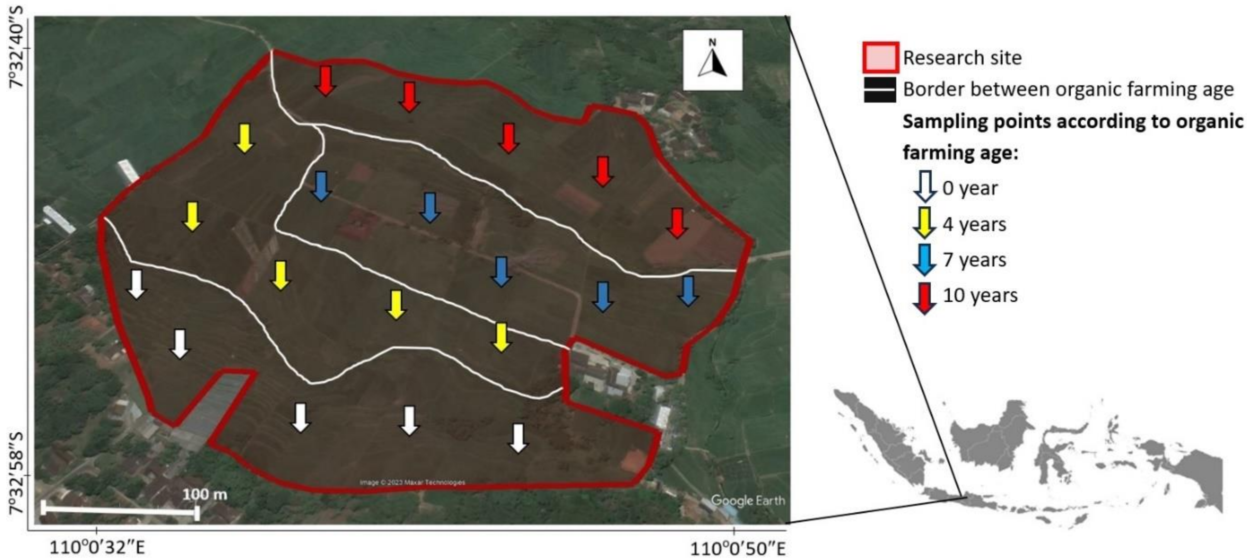


**Figure 1**. Study site and sampling points

The sticky limit, plastic limit, and color-changing limit using the gravimetric method (Raad Al-Adhadh et al., 2020), take about 15 g of air dry soil, put it in evaporation plate and mix with distilled water until a mass becomes plastic enough to easily form into a ball. Take some of this ball weighing about 8 g for the test sample, then the sample that has been tested is baked in the oven for 4 hours at 105°C. Soil friability is the difference between the sticky and plastic limits (Munkholm, 2011). Furthermore, analyzing dissolved organic C involves measuring light absorption by dissolved organic carbon using a spectrophotometer (Bolan et al., 1996). The dissolved organic carbon was extracted with distilled water (aquades) and then measured using total organic carbon analysis (Jones & Willett, 2006). In addition, total soil N was analyzed using the Kjeldahl method, and total P and total K were determined using the 25% HCl extract method. Available S was analyzed by the Morgan Wolf extract method. The available K, exch.Ca, exch.Na, CEC, and base saturation were analyzed using the 1N Ammonium Acetate Extraction method pH 7 (Sparks et al., 2020). Finally, soil carbon sequestration was calculated using Equation 1 (Oliveira et al., 2016).

$$C_{Stock} = (SOC)(BD)(T) \quad [1]$$

Where $C_{stock}$ is given in Mg ha$^{-1}$, [SOC] is total carbon concentration (dag.kg$^{-1}$), BD is bulk density (Mg.cm$^{-3}$), and T is soil depth (cm).

## 2.3. Data analysis

Statistical analysis used Principal Component Analysis to determine selected primary variables in organic rice farming, linear and power regression to determine the variables' trend, one-way ANOVA to determine the differences of variables at organic farming ages, Pearson's correlation test to identify the correlation between soil organic carbon with all variables, and multivariate analysis to determine the variables determining soil organic carbon and rice yield, respectively.

# 3. RESULTS

The main purpose of amending organic matter in the soil is to maintain and increase the soil organic carbon. Figure 2 shows the soil organic carbon content in soil at 0, 4, 7 and 10 years of organic rice farming age. Figure 2 shows that soil organic carbon is significantly higher along with the organic farming age. It is shown the soil organic carbon was only 1.84% at 0 years, but became 2,79% in the 10$^{th}$ year, which means the soil organic carbon increased by 51.63% within 10 years. The soil organic carbon increased speedily in the first 4 years which is 29% (from 1.84 to 2.28% at o and 4 years of age, respectively), or 7.3% per year. Then it gradually increased until the 10$^{th}$ year with an average increasing rate of approximately 3% per year.

Besides the soil organic carbon, organic farming age also improved other soil properties. Table 1 shows the other soil properties with the LSD test between organic farming ages. It is clearly shown in Table 1 that organic farming improved all the soil properties, especially after 4 years. The C stock was the lowest at 0 years of organic farming (37.01 Mg.ha$^{-1}$), while it was 43.86 – 46.82 Mg.ha$^{-1}$ (18.5-26.5%) higher after 4-10 years of organic farming. The population of microbial C also significantly 43-69% higher (0.33-0.39 μg.g$^{-1}$) than in 0 years (0.23 μg.g$^{-1}$). After 4 years of organic farming, the soil properties also significantly improved until 10 years, i.e.: soil liquid limit (4.6-5.7%), sticky limit (7.6-8.6%), plastic limit (2.9-4.6%), color changing limit (10-14.6%), friability (16-17.5%), total nitrogen (30-103%), total phosphorus (21.2-37.7%), total potassium (99-150%), exchangeable sodium (8-26.7%), cation exchange capacity (35.8-60%), and base saturation (28.4 to 58.6%).

On the other hand, soil properties improved after 7 years to 10 years of organic farming including dissolved organic carbon (3-17.8%), soil bulk density (8.7-14.7%), porosity (7.4-14%), exchangeable potassium (8-28%), available sulfur (4-24%), and exchangeable calcium (8-28%).

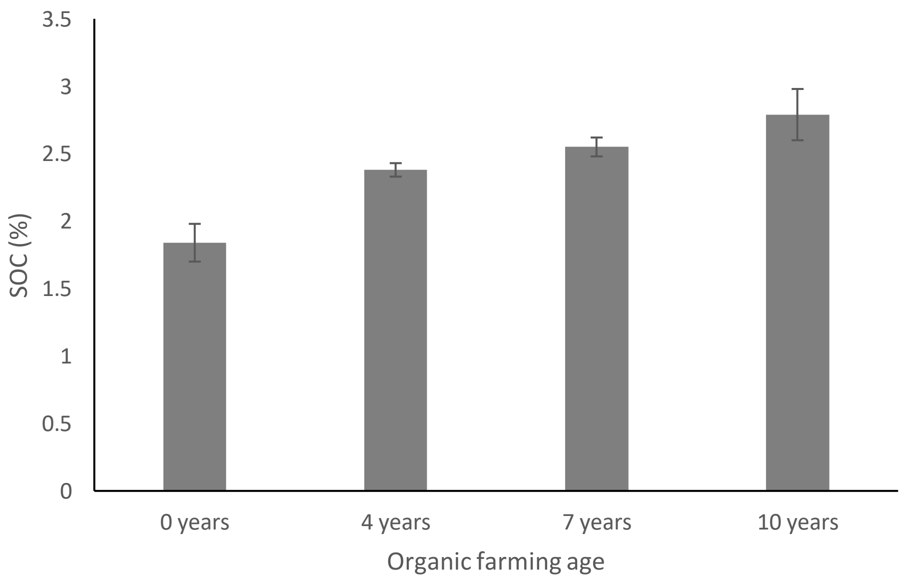


**Figure 2.** Soil organic carbon (SOC) content at each organic farming age

**Table 1.** Soil properties on organic farming age

| No. | Soil Properties | Organic farming age | | | |
|---|---|---|---|---|---|
| | | 0 year | 4 years | 7 years | 10 years |
| 1. | C Stock (Mg $ha^{-1}$) | 37.01 ± 5.03 b | 43.84 ± 3.78 a | 43.86 ± 4.2 a | 46.82 ± 3.17 a |
| 2. | Microbial C (µg $g^{-1}$) | 0.23 ± 0.008 d | 0.33 ± 0.008 b | 0.38 ± 0.007 a | 0.39 ± 0.012 a |
| 3. | Dissolved Organic C (%) | 0.039 ± 0.001 c | 0.041 ± 0.002 bc | 0.042 ± 0.001 b | 0.046 ± 0.002 a |
| 4. | Bulk density (g $cm^{-3}$) | 0.98 ± 0.1 a | 0.92 ± 0.08 ab | 0.85 ± 0.10 b | 0.84 ± 0.05 b |
| 5. | Liquid limit (%) | 63.89 ± 2.03 c | 67.70 ± 1.49 a | 67.51 ± 0.87 a | 68.21 ± 0.57 a |
| 6. | Sticky limit (%) | 61.98 ± 0.72 c | 67.24 ± 0.66 a | 66.66 ± 0.67 a | 67.30 ± 0.72 a |
| 7. | Plastic limit (%) | 41.02 ± 0.92 c | 42.91 ± 0.60 a | 42.22 ± 0.23 ab | 42.70 ± 0.70 a |
| 8. | Color changing limit (%) | 22.65 ± 0.12 d | 25.95 ± 0.86 a | 24.93 ± 0.36 b | 25.63 ± 0.06 a |
| 9. | Soil friability (%) | 20.97 ± 0.23 c | 24.32 ± 0.32 a | 24.44 ± 0.47 a | 24.64 ± 0.53 a |
| 10. | Porosity (%) | 56.72 ± 5.90 b | 59.92 ± 3.40 ab | 62.94 ± 3.60 a | 63.45 ± 2.14 a |
| 11. | Total Nitrogen (%) | 0.23 ± 0.02 e | 0.29 ± 0.02 c | 0.37 ± 0.02 b | 0.45 ± 0.03 a |
| 12. | Total Phosphorus (ppm) | 7.45 ± 0.51 d | 9.17 ± 0.99 bc | 10.09 ± 0.52 ab | 10.39 ± 1.34 a |
| 13. | Total Potassium (ppm) | 28.20 ± 6.57 e | 56.19 ± 3.95 c | 62.45 ± 3 b | 70.42 ± 4.14 a |
| 14. | Exch. Potassium (cmol(+) $kg^{-1}$) | 1.92 ± 0.16 a | 1.74 ± 0.20 a | 1.48 ± 0.15 b | 1.36 ± 0.23 b |
| 15. | Available Sulfur (ppm) | 0.71 ± 0.05 d | 0.74 ± 0.04 bd | 0.79 ± 0.05 b | 0.88 ± 0.06 a |
| 16. | Exch. Ca (cmol(+) $kg^{-1}$) | 14.70 ± 1.12 b | 15.86 ± 0.99 b | 17.88 ± 0.87 a | 18.61 ± 1.38 a |
| 17. | Exch. Na (cmol(+) $kg^{-1}$) | 7.65 ± 0.42 a | 5.80 ± 0.21 c | 5.93 ± 0.64 c | 7.11 ± 0.29 ab |
| 18. | CEC (cmol(+) $kg^{-1}$) | 30.44 ± 1.16 e | 41.33 ± 1.67 c | 44.86 ± 1.88 b | 48.78 ± 1.22 a |
| 19. | Base saturation (%) | 0.88 ± 0.04 a | 0.63 ± 0.04 c | 0.62 ± 0.02 c | 0.60 ± 0.04 c |

**Remarks** : Mean followed by the same letter within the same row indicate not significant difference at α= 0.05 by LSD test

**Table 2.** Correlation between organic C and various soil properties

| No. | Soil Properties | r (correlation coefficient) |
|---|---|---|
| 1. | C Stock | 0.679** |
| 2. | Microbial C | 0.895** |
| 3. | Dissolved Organic C | 0.702** |
| 4. | Bulk density | -0.590** |
| 5. | Liquid limit | 0.582** |
| 6. | Sticky limit | 0.820** |
| 7. | Plastic limit | 0.599** |
| 8. | Color changing limit | 0.764** |
| 9. | Soil friability | 0.833** |
| 10. | Porosity | 0.590** |
| 11. | Total Nitrogen | 0.839** |
| 12. | Total Phosphorus | 0.672** |
| 13. | Total Potassium | 0.858** |
| 14. | Exch. Potassium | -0.724** |
| 15. | Available Sulfur | 0.653** |
| 16. | Exch. Ca | 0.672** |
| 17. | CEC | 0.937** |
| 18. | Base saturation | -0.847** |

**Remarks** : Asterisks (**) indicate a highly significant correlation between soil properties and organic C at the α=0.01 of the Pearson correlation test

Table 2 shows all soil properties correlated with organic C ($P<0.01$) with strong correlation, indicated with coefficient (r) bigger than 0.5. Soil organic C is positively and significantly correlated with microbial C (r=0.895**), dissolved organic C (r=0.702**), porosity (r=0.590**), total N (r=0.839**), total P (r=0.672**), total K (r=0.858**), and CEC (r=0.937**). However, a significant negative correlation was found between soil organic C and bulk density (r=-0.590**), exch. K (r=-0.724**), and base saturation (r=-0.847**).

Furthermore, Figure 3 shows the principal component analysis, which helps to determine the principal components which were really affected by the organic farming ages. This analysis reduces some variables which may not contribute as principal variables in the organic farming age to more simple variables without changing the pattern. It can be seen in Figure 3 that the organic farming age specifically improved soil organic carbon, soil carbon stock, soil microbes population, dissolved organic carbon, soil liquid limit, soil sticky limit, soil plasticity limit, soil color changing limit, soil friability, soil porosity, soil total nitrogen, soil total phosphorus, soil available sulfur, exchangeable calcium, cation exchange capacity, and total potassium. However, among all the soil variables, the multivariate analysis in Table 3 indicates that soil organic carbon, which is the most important variable in organic farming, is determined by only three variables, namely cation exchange capacity, total phosphorus, and soil porosity with the following model (Eq. 2), with coefficient of determinant ($R^2$)= 0.982.

$$SOC = 0.875 + 0.034\,CEC + 0.175\,Total\ P - 0.025\,porosity \quad \text{[2]}$$

Where: SOC= soil organic carbon (%); CEC= cation exchange capacity (cmol $kg^{-1}$); Total P= total soil phosphorus (ppm); and porosity= soil porosity (%)

Rice yields at 0-10 years of organic rice farming are shown in Figure 4. Figure 4 figures out rice fields managed under organic farming increased over the years. Rice yield increased 14.7% (from 6.6 to 7.6 tons.$ha^{-1}$) at the first 4 years, but then jumped to 10.4 tons.$ha^{-1}$ after 7 years (57%). Then, the yield slightly increased after 10 years to 10.52 tons.$ha^{-1}$, which is only 2% from the 7th year. Multivariate analysis between rice yields with all the soil variables shown in Table 4 shows that soil total Nitrogen is the only soil variable that influenced the rice yield, with the model presented in Equation 3. The model resulted in coefficient determinant ($R^2$)= 0.496.

$$Yield = 1.650 + 22.590\, Total\ N \quad [3]$$

Where: Yield= rice yield under organic farming (tons.ha$^{-1}$); Total N= total soil nitrogen in organic farming (%)

Figure 5 shows the linear regression of soil organic carbon and total nitrogen, which shows that in organic rice farming, the total soil nitrogen increased along with the soil organic carbon increase. The increase of 1% or soil organic carbon increases total Nitrogen 0.065% ($R^2$=0.9177).

## 4. DISCUSSION

Organic rice farming age distinctly improved soil organic carbon (Figure 2), because the discontinuation of chemical input replaced with continuous input of organic matter creates healthy soil ecological conditions, indicated by the high levels of microbial C (Table 1). This is in line with research by Naresh et al. (2017), which revealed that the high microbial C content was caused by the accumulation of organic C compounds from plant residues and organic fertilization on the soil surface. Applying organic fertilizers improves soil quality and health by increasing soil carbon and microorganisms beneficial to plants (Gaind & Singh, 2016). The number, diversity, and activity of soil microorganisms are directly related to organic matter, a food source for microorganisms (Victoria et al., 2012).

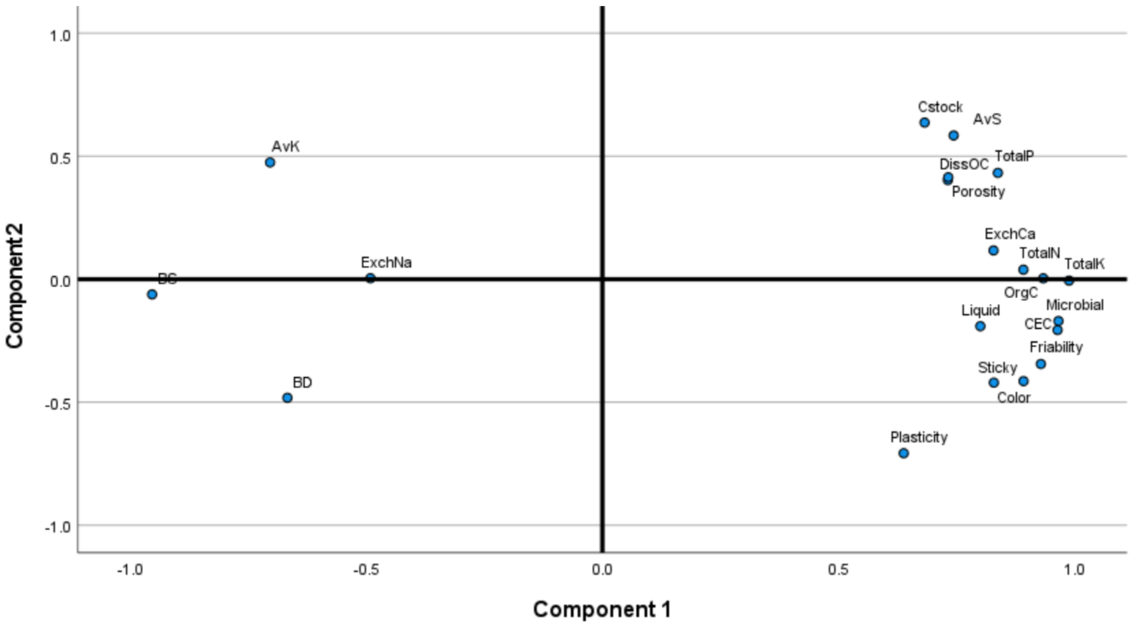


**Figure 3**. Principal soil component analysis in organic farming

**Notes:** OrgC (soil organic carbon); Cstock (soil carbon stock); microbial (soil microbes population); DissOC (dissolved organic carbon); BD (soil bulk density); Liquid (soil liquid limit); Sticky (soil sticky limit); Plasticity (soil plasticity limit); Color (soil color changing limit); Friability (soil friability), Porosity (soil porosity); TotalN (soil total nitrogen); TotalP (soil total phosphorus), AvK (soil available potassium); AvS (soil available sulfur); ExchCa (exchangeable calcium); ExchNa (exchangeable sodium); CEC (cation exchange capacity); BS (base saturation); TotalK (total potassium)

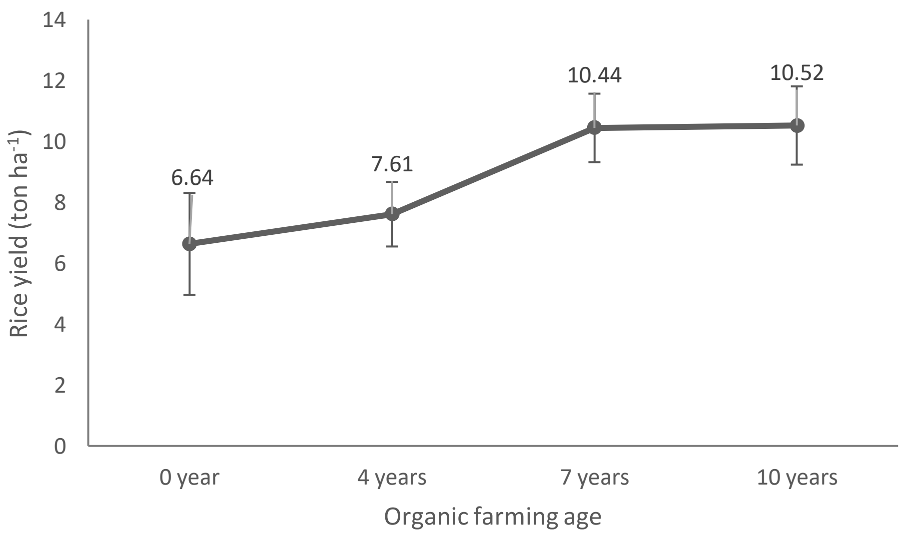


**Figure 4**. Rice yield at organic farming age

**Table 3**. Multivariate analysis of soil organic carbon (dependent variable) with various soil properties

| Model | | Unstandardized Coeff. B | Unstandardized Coeff. Std. Error | VIF | Sig. | $R^2$ |
|---|---|---|---|---|---|---|
| 3 of 4 | (Constant) | 0.875 | 0.249 | | | |
| | Cation exchange capacity | 0.034 | 0.04 | 2.108 | <0.001 | 0.982 |
| | Total phosphorus | 0.175 | 0.023 | 3.226 | | |
| | Porosity | -0.025 | 0.006 | 2.500 | | |

**Notes:** Dependent variable: soil organic carbon; independent variables input: C-stock, soil microbial, dissolved organic carbon, soil bulk density, soil liquid limit, soil sticky limit, soil plasticity limit, soil color changing limit, soil friability, soil porosity, soil total nitrogen, soil total phosphorus, soil available potassium, soil available sulfur, exchangeable calcium, exchangeable sodium, cation exchange capacity, base saturation, and total potassium.

**Table 4**. Multivariate analysis of yield (dependent variable) with various soil properties

| Model | | Unstandardized Coeff. B | Unstandardized Coeff. Std. Error | VIF | Sig. | $R^2$ |
|---|---|---|---|---|---|---|
| 1 of 1 | (Constant) | 1.650 | 2.361 | | 0.011 | 0.496 |
| | Soil total nitrogen | 22.590 | 7.198 | 1.000 | | |

**Notes:** Dependent variable: yield; independent variables input: soil organic carbon, carbon stock, soil microbial, dissolved organic carbon, soil bulk density, soil liquid limit, soil sticky limit, soil plasticity limit, soil color changing limit, soil friability, soil porosity, soil total nitrogen, soil total phosphorus, soil available potassium, soil available sulfur, exchangeable calcium, exchangeable sodium, cation exchange capacity, base saturation, and total potassium

The high soil organic carbon in organic farming also improved almost all the soil properties (Table 1), since soil organic carbon strongly correlated with all the soil properties (Table 2). This means the improvement of soil organic carbon eventually improved soil conditions too, especially after 4 years of organic farming. However, among those soil properties, there are some properties that is synergically affected by the organic farming age, namely soil organic carbon, soil carbon stock, soil microbes population, dissolved organic carbon, soil liquid limit, soil sticky limit, soil plasticity limit, soil color changing limit, soil friability, soil porosity, soil total nitrogen, soil total phosphorus, soil available sulfur, exchangeable calcium, cation exchange capacity, and total potassium (Figure 3). Those variables improved along with the organic farming age. Regarding the soil porosity improvement, this is in line with Malau and Utomo (2017), who found that continuously adding organic matter to the soil for an extended period led to the soil becoming porous. The application of manure undergoes a decomposition process that produces humus that interacts with soil particles to create a balanced soil structure (Lawenga et al., 2015).

However, this study confirms finally soil organic carbon in the 0-10 years of organic rice farming stipulated by cation exchange capacity, total soil phosphorus, and soil porosity after further selection of variables through multivariate analysis (Equation 2). The model reveals that soil organic carbon increases when cation exchange capacity and total soil porosity increase, but it decreases when porosity increases. From this model, it can be said that long-term organic farming maintains and improves mostly these 3 variables (cation exchange capacity, total soil phosphorus, and soil porosity), hence the soil organic carbon was well supported.

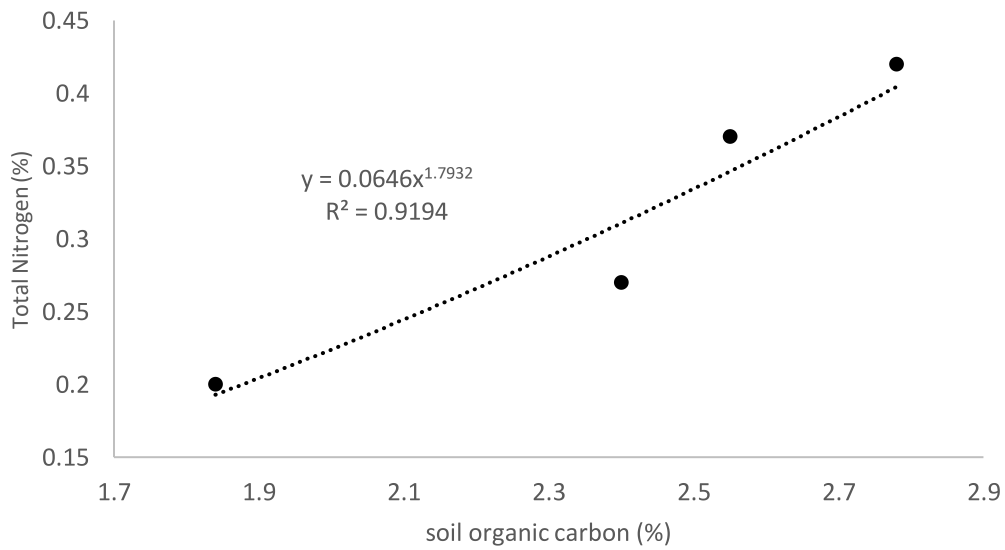


**Figure 6**. Power regression of soil total Nitrogen and organic carbon from 0, 4, 7, and 10 years of organic rice farming at the research site

The high soil organic matter content causes an increase in CEC due to the presence of a high total negative ionic charge on the surface of the organic matter humus, enabling it to attract and hold cations (Tomašic et al., 2013). Organic matter decomposition produces humus, and about 20-70% of soil's CEC generally comes from humus colloids, so there is a correlation between organic matter and soil CEC (Agegnehu et al., 2014; Loso et al., 2020). The CEC reflects the ability of soil colloids to absorb and exchange cations in the soil. The higher the CEC, the greater the ability of the soil to absorb and exchange its nutrients (Susila, 2013).

Organic rice farming supports rice yield, especially after 7 years (Figure 4). This is in line with Hossain and Sarker (2016) and Hammad et al. (2020) who found that organic rice farming not only improves physical, chemical, and biological soil properties but also improved crop yield and quality. It is also confirmed that rice yield in organic rice farming is mostly determined by total soil nitrogen among all the soil properties (Equation 3). This model shows that the increase of 1% total soil Nitrogen increases 1.88 tons $ha^{-1}$ rice yield. This is in line with research by Wang et al. (2015), who found that organic farming resulted in high total soil nitrogen. According to Karasawa et al. (2015), the high accumulation of nitrogen was due to an increase in the activity of various soil enzymes that support nitrogen mineralization, then nitrogen will be transported to the rice grain (Khan et al., 2018).

Finally, this study verifies that the improved soil organic carbon in the long-term of organic farming implementation does not directly support the rice yield, but through the total soil nitrogen. Therefore, it is very important to maintain and improve soil total nitrogen. However, the soil total nitrogen in the 0-10 years of organic rice farming can be predicted using soil organic carbon information with a power regression (Figure 5). It confirms that soil total nitrogen will increase by 0.065% when there is an increase of 1% of soil organic carbon and will be followed by the rice yield increase by 1.66 $tons.ha^{-1}$. That is because better soil carbon sequestration increases biological N fixation and reduced nitrogen gaseous losses from soil hence promotes bigger crop biomass (Cong et al., 2015).

## 5. CONCLUSION

Organic rice farming improved physical, chemical and biological soil properties after 4 years of implementation, while the high rice yield resulted in the organic farming can be seen distinctly after 7 years. Among all the soil properties, cation exchange capacity, total soil phosphorus and soil porosity are primarily contributed to soil organic carbon in the organic rice farming. In the meantime, rice yield is majorly determined by soil total nitrogen. Therefore, increasing soil total nitrogen by adding organic matter to improve soil organic carbon will increase rice yield along with the improvement in soil properties. Further study on soil properties in the longer term (more than 10 years) of organic farming age is important to provide evidences regarding the sustainable agriculture practices.


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## Declaration of Competing Interest

The authors declare that no competing financial or personal interests that may appear and influence the work reported in this paper.

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