Soil physical and chemical fertility dynamic under organic, semi organic and conventional rice farming systems on Termas Village, Sambung Macan District, Sragen Regency

Damasus Riyanto¹, Sukristiyonubowo² dan Sugeng Widodo¹
¹Indonesian Agency for Agricultural Research and Development
Yogyakarta Assessment Institute for Agricultural Technology, Stadion Maguwohardjo Street No. 22 Karangsari, Sleman, D.I. Yogyakarta
²Indonesian Agency for Agricultural Research and Development, Soil Research Institute, Tentara Pelajar Street no. 12 Bogor

Email : damasriy4n@yahoo.co.id

Abstract. Rice productions and qualities of organic rice farming is better than conventional rice farming system, therefore, rice yields have been sold to abroad. The aims of this study was to evaluate the dynamic of soil fertility in term soil physical and chemical at organic, semi organic and conventional rice farming systems at Sambung Macan, Sragen Regency. The study was conducted at rice farming in Termas Village, Sambung Macan, from March 2017 to 2018. Soil composites were taken from ten points of organic, semi organic and conventional farming systems before ploughing. The soil samples were analysed for physical and chemical properties at Laboratory Balai Pengkajian Teknologi Pertanian, Yogyakarta. The results indicated that chemical soil fertility at 2018 was better than 2017 including soil pH, soil organic C, N total, P and K extracted with HCl 25 %, as well as physical soil fertility, namely BD soil in semi-organic and organic is lower than conventional systems, permeability in organic cultivation is higher than in semi-organic and conventional cultivation.

1. Introduction
The farmers realize that Green Revolution technology, combination between high external inputs (fertilizer and pesticides) and high yielding varieties, is not sustainable, production cost become more expensive and rice production tend to decrease. Some farmers want to move to other rice farming systems, some want to change to organic farming system, some to semi organic and the rest still doing conventional system with some improvement [1]. The term of organic refers to a process that uses methods respectful of the environment, from production stages through the handling and processing. Organic farming is not only concerned with the product, but also the whole system used to produce and deliver the product to the ultimate consumers [2]. In organic farming systems avoid applications of chemical fertilizers and commercial pesticides, rely on organic inputs and recycling for nutrient supply, and emphasize on cropping system design and biological processes for pest management [3]. Semi organic rice farming means free from using chemical product, but the farmers still use Urea as much as 50 kg ha⁻¹ at 21 days after planting. While in the conventional rice farming system, the farmers still use mineral fertilizer and commercial pesticides. They still apply green revolution technology with straw compost. In Indonesia, the yields and quality of organic rice and vegetables farming systems are better than conventional. Some of them are sold in the foreign countries (as export commodities) in Europe, Thailand, Singapore and Malaysia.

In some countries, research in organic farming systems have been developed both in plot, farm and community scales with different purposes. Some advantages of organic rice and vegetables are reported by researchers. According to Sukristiyonubowo et al. (2018) soil chemical-physical fertility in organic field in Kopeng Village, Semarang Regency, was more superior than in conventional vegetables farming system including soil pH, C organic and N, P and K total, bulk density, particle density, soil porosity and permeability (slow and fast drainage) [4]. In Bogor Regency, the soil chemical, physical and biological properties of organic vegetable farming are better.
than conventional farming systems in term of soilpH, organic C, total N, P, and K extracted with HCl 25%, bulk density and dehydrogenase enzyme [5]. Similar results was reported in rice farming in Sambirendjo Sub District, Sragen Regency, the soil chemical-physical fertility in organic field in Sambirendjo Sub District, Sragen Regency, was more superior than both in semi organic and conventional and in semi organic was better than in conventional system in terms of soil pH, organic C and N, P and K total, bulk density, particle density, soil porosity and permeability. The similar finding was also observed in rice biomass production. Future research question is how long the organic farming system without external input sustains the production and soil fertility [6]. Furthermore, Prakhaset et al. (2002) reported that rice planted in organic technology has better inmilling and cooking quality like total and head milled rice recovery, protein content, kernel elongation and lower in amylose content than cultivated unconventional system with commercials fertilizers and pesticides [7]. Zhang and Shao (1999) reported that higher protein grains content will result in higher head rice recovery and lower amylose content [8]. Chino et al. (1987) found that in the organic cultivation, the asparagine’s content of plant phloem sap is significantly lower than in conventional systems [9]. Kajimura et al. (1995) reported that the low densities of Brown Plant Hopper and White Backed Plant Hopperare observed in organic fields [10]. Similar finding was reported by Alice et al. (2004) [11]. In line with the soil, organic farming is usually associated with a significant higher level of biological activities and soil organic matter than in green revolution technology (Oehl et al. 2004; Maderet al. 2002; Hansen et al. 2000; Stolze et al. 2002) [12] [13] [14] [15]. In fact, there are still limited studies on comparing organic versus conventional systems [16]. In conventional rice farming system, profitable and sustainable agriculture management should be addressed at supplying sufficient nutrients input for optimum crop growth and development as well as farmers income, with keeping losses to environments at the minimum level. Inputs addition for right amount nutrient through fertilizers should be based on characteristic soil fertility status and crop being planted. Combined uses of mineral and organic fertilizers (recycling rice straw, crop residues, compost, and manures) are also recommended in conventional or non-organic farming system (Fenninget al. 2002; Hasegawa et al. 2005; Yang et al. 2007; Sukristiyonubowo and Tuherkih 2009) [17] [18] [19]. The aimed of this research was to study the soil chemical-physical dynamic under organic, semi organic and conventional rice farming systems in Termas Village, Sambung Macan Sub District, Sragen Regency.

2. Materials and Methods

The experiment was conducted at Vertisols Termas Village, Sambung Macan Sub District of Sragen Regency for conventional, semi organic and organic rice farming systems from March 2017 to 2018. In semi organic rice farming, the farmers apply nitrogen fertilizer as much as 50 kg ha\(^{-1}\) season\(^{-1}\) 21 days after transplanting, while in organic rice farming they apply only organic fertilizer as much as 2-5tons ha\(^{-1}\) every cropping season. In rice conventional systems, they usually use mineral fertilizer and organic fertilizer as much as 200 kg ha\(^{-1}\)urea, 100 kg ha\(^{-1}\) PONSKHA and 50 kg KCl ha\(^{-1}\) season\(^{-1}\) and use straw compost about 0.5ton ha\(^{-1}\). In Sragen Regency, they start organic and semi organic rice farming systems since 1999.

Composite soil samples of 0-20 cm in depth were taken in March 2017 and 2018, before soil preparation and submitted to the laboratory of AIAT (Assessment Institute for Agricultural Technology) in Jogjakarta for analysing. One kg soil composite was collected from ten sampling points at every site and mixed. These samples were submitted to the Soil Analytical Laboratory of the Jogjakarta Assessment Institute for Agricultural Technology for analyses of chemical and physical properties of the soils. Chemical analyses included the measurement of pH (H\(_2\)O and KCl), organic matter, phosphorus, and potassium, Organic matter was determined using the Walkley and Black method, pH (H\(_2\)O and KCl) was measured in a 1:5 soil-water suspension using a glass electrode, total P and soluble P were measured colorimetrically, extracted using HCl 25% and Olsen methods, respectively. The total K was extracted using HCl 25% and subsequently determined by flame-spectrometry [19]. Physical analyses included the measurement of water level, particle density (PD), bulk density (BD) and total pore space. Water level was measured by Gravimetric method, particle density was measured using Richards and Fireman method, bulk density was measured by Richards
method and total pores space was measured using De Boedt method. All measurement of physical properties adopted from Indonesian Soil Research Institute.

3. Results and Discussion

3.1. Soil Chemical Properties

The soil chemical properties are presented in Table 1. Compared to 2017, the soil chemical fertility sampled in 2018 was better than in 2017 including pH, C-organic, N-total, P and K extracted with HCl 25%.

In 2018, soil pH were neutral both in the organic and semi organic farming systems, but in conventional rice farming tend to slightly acid. The neutral of soils pH may be due to organic materials (compost and manure) added by the farmers, while for slightly acid in conventional due to fertilizer (Urea) applied by the farmers. The level of soil organic carbon (SOC) was classified as height in organic and semi organic rice farming system and higher than in conventional rice farming systems. According to Sommerfeldt et al. (1988) and Clark et al. (1998), they stated that the higher soil OM levels in soils managed with animal manure and cover crops than in soils without such inputs [22][23]. The soil total N in organic, semi organic and conventional fields considered as medium due to addition of organic material (manure and compost) in organic and semi organic, and because of application of Urea and compost in conventional field. In year 2018, the CEC in organic fields (38.40 cmol/kg) was better than in semi organic (15.73 cmol/kg) and conventional (13.38 cmol/kg) rice farming and in semi organic was higher than in conventional system. This due to the farmers applied different in organic materials and different in rates (manure and straw compost) that can build the colloids.

Table 1. Soil chemical dynamic under three rice farming systems in Termas Village, Sambung Macan District, Sragen Regency

| Parameters                        | Organic 2017 | Organic 2018 | Semi organic 2017 | Semi organic 2018 | Conventional 2017 | Conventional 2018 |
|----------------------------------|--------------|--------------|--------------------|--------------------|------------------|-----------------|
| pH(H2O)                          | 6.9          | 7.63         | 6.6                | 7.56               | 6.0              | 6.40            |
| C-Organic                        | 3.2          | 3.85         | 2.7                | 3.04               | 1.3              | 2.61            |
| N-Total                          | 0.28         | 0.43         | 0.25               | 0.37               | 0.17             | 0.33            |
| P extracted with 25% HCl         | 62.3         | 134          | 48.9               | 90                 | 41.7             | 81              |
| K extracted with 25% HCl         | 37.7         | 170          | 32.3               | 65                 | 19.7             | 64              |
| CEC (cmol/kg)                    | 38.40        | 15.73        | 32.3               | 65                 | 19.7             | 64              |

For three rice farming systems, organic, semi organic and conventional rice farming, P extracted with HCl 25% classified as very height, suggesting that application of mineral fertilizer in conventional farming system, application of 2-5 tons manure ha\(^{-1}\) season\(^{-1}\) in organic system can increase the availability of P. While, the P extracted with HCl 25% in conventional rice farming system was also considered high, suggesting application of 100 to 150 kg SP-36 ha\(^{-1}\) season\(^{-1}\) done by farmers increased the availability of P. Total K in rice organic farming system was considered very high, higher than in semi organic and conventional farming systems, indicating that application of 2 to 5 ton organic materials (manure and straw compost) was enough to increase the total K in the soil. It was suggesting that straw compost applied was rich in K content. Whereas, in conventional farming system was considered lower than organic farming indicating that addition of about 50 kg KC\(_{1}\)ha\(^{-1}\) season\(^{-1}\) was not superior as straw compost. Clark et al. (1998); Rasmussen and Parton (1994) and Wander et al. (1994) also reported similar findings [23][24][25].

Therefore, it may be concluded that in 2018 the rice organic farming system in general was better than in semi organic and conventional rice farming system including pH, C-organic, nitrogen content, and P, and K extracted with 25% HCl. Furthermore, in the conventional rice farming system applications of proper mineral fertilizers to improve inherent soil fertility leading to rice yield is a must.
In 2017, in general the soil chemical fertility under organic fields was better than in semi organic and conventional, and in semi organic was more excellent than conventional rice farming including pH, C-organic, N-total, P and K extracted with HCl 25 %.

3.2. Soil Physical Properties

The soil physical properties are presented on Table 2. In 2017, the soil texture class was clay loam in organic, semi organic and in the conventional fields, but in 2018 the texture of the soil in semi organic and conventional became clay. These may be clay fraction in semi organic (54 %) and conventional (57 %) became dominant.

In general, soil physical analysis sampled in 2017 showed that in the organic field, the soil physical properties including bulk density, particle density, soil porosity and permeability were better than in the semi organic and conventional fields. In organic cultivation, the bulk density was 0.95 g/cm³ compared to conventional rice farming was 1.21 g/cm³, the particle density in organic fields was 2.44 g/cm³ in the conventional was 2.59 g/cm³. Soil porosity in organic was 68.7 % and in conventional system was 50.2 %. This can be happened, because soil organic matter could arrange aggregates incorporated each other and physically becoming stabilized within macro aggregates. Hence the soil was more porous and total soil porosity was higher compare to the soil porosity in the conventional rice. According to Pirngadi (2009) the organic matter applied to the rice fields can elevate the water holding capacity, improve the soil structure to be crumbly, prevent the soil aggregates become more slowly [27]. In addition, the soil with enough soil carbon content can easily improve soil tillage and usually more porous compared to the conventional rice farming system, which usually has lower soil carbon organic content and use inorganic fertilizer. Furthermore, Mandal et al. (2003) reported that application of green manure (Sesbania radiata) together with different rates of nitrogen fertilizer application increased the concentration of soil organic matter and total nitrogen, improved total pore space, water stable aggregates, hydraulic conductivity, and reduced bulk density [26].

Table 2. The soil physical properties under three rice farming systems in Termas Village, Sambung Macan District, Sragen Regency

| Parameters                  | Organic 2017 | Organic 2018 | Semi organic 2017 | Semi organic 2018 | Conventional 2017 | Conventional 2018 |
|-----------------------------|--------------|--------------|-------------------|-------------------|-------------------|-------------------|
| Bulk Density (gr.cm⁻³)      | 0.95         | 0.68         | 1.10              | 0.73              | 1.21              | 0.87              |
| Particle Density (gr.cm⁻³)  | 2.44         | 1.86         | 2.52              | 2.28              | 2.59              | 2.26              |
| Soil Porosity (%)           | 68.7         | 68           | 56.1              | 56                | 50.2              | 53                |
| Permeability (cm.hour⁻¹)    | 1.14         | 1.09         | 0.48              | 0.58              | 0.56              | 0.11              |

In general, soil physical fertility taken in 2018 was more excellent than in 2017 including soil pH, bulk density, particle density, soil porosity and permeability. In the organic rice field, the soil physical properties including bulk density, particle density, soil porosity and permeability were better than in the semi organic and conventional fields. In organic fields, the bulk density was 0.68 g/cm³ compared to conventional rice farming was 0.87 g/cm³, the particle density in organic rice fields was 1.86 g/cm³ in the conventional was 2.26 g/cm³. The soil porosity in organic was 68 % and in conventional system was 53 %. This can be happened because of higher soil organic in organic field. Hence the soil was more porous and total soil porosity was higher compare to the soil structure in the conventional rice. According to Pirngadi (2009) the organic matter applied to the rice fields can elevate the water holding capacity, improve the soil structure to be crumbly, prevent the soil aggregates become more slowly [27]. In addition, the soil with enough C soil content can easily improve soil tillage and...
usually more porous compared to the conventional rice farming system, which usually has lower C organic content and use inorganic fertilizer. Furthermore, Mandal et al. (2003) reported that application of green manure (Sesbaniarostrata, Sesbania aculeata, and Vigna radiata) together with different rates of nitrogen fertilizer application increased the concentration of soil organic matter and total nitrogen, improved total pore space, water stable aggregates, hydraulic conductivity, and reduced bulk density [26].

4. Conclusion
The soil chemical and physical fertilities sampled in 2018 were better than soil taken in 2017 including soil pH, C-organic, N-total, P and K extracted with HCl 25 %, bulk density, particle density, soil porosity and permeability. Improving soil chemical and physical fertilities can be done by addition of organic matter materials (manure, straw compost and green manure) about 2-5 tons ha\(^{-1}\) season. It was done by the farmers in Sragen Regency. The impact is not only for improving soil chemical and physical soil fertilities, but also increasing biological soil properties.

Acknowledgments
We thank to Minister of Agriculture, Republic of Indonesia for funding this experiment. To Mr. Ryan Christie WA for taking soil and rice samples the field.

References
[1] Sukristiyonubowo R and Riyanto D. 2018 Indonesian Soil and Climate Journal. Vol 39 (1): p. 19 – 24
[2] Anonymous. 2004. Organic Farming Agriculture. Nature Journal Volume 428: p.796 – 798
[3] Rigby and Caceres 2001. Organic faming and the sustainability of agricultural system. Agriculture System, 68. p. 21-40.
[4] Sukristiyonubowo, Benito HP and Edi H. 2015 Indonesian Soil and Climate Journal. Vol 42 (1): p. 53 – 56
[5] Sukristiyonubowo, Ajiputro R and Sugeng W. 2015 Indonesian Soil and Climate Journal. Vol 39 (2): p. 121 – 126
[6] Sukristiyonubowo, Damasus R and Sugeng W. 2018 Move to organic farming: Chemical and physical soil properties of organic and conventional vegetables reasons. Paper presented at International Seminar Series: Horticulture for the quality life, held in IPB International Convention Center Bogor, December 10\(^{th}\), 12 p
[7] Prakhas YS, Bhadoria PBS, and Rakshit A. 2002. Relative efficiency of organic manure in improving milling and cooking quality of rice. IRRN. 27(1):43 – 44.
[8] Zhang M and Zhenli H 2004 Geoderma. 118: 167-179
[9] Chino M, Hayashi M, and Fukumorita T. 1987 Journal Plant Nutrition 10: 1651-1661.
[10] Kajimura T, Fujisaki K, and Nagasuji F. 1995 Applied Entomology Journal. 30:12–22
[11] Alice J, Sujeetha RP, and Venugopal MS. 2004 IRRN, 28 (2): 36 – 37
[12] Oehl F, Sieverding E, Mäder P, Dubois D, Ineichen K, Boller T, and Wiemken A. 2004. Impact of long-term conventional and organic farming on the diversity of arbuscular mycorrhizal fungi. Oecologia. 138: 574-583
[13] Mäder P, Fliessbach A, Dubois D, Gunst L, Fried P, and Niggli U. 2002. Soil fertility and biodiversity in organic farming. Science, 296, 1694-1697
[14] Hansen B, Kristensen ES, Grant R, Hogh Jensen H, Simmelsgaard SE, and Olesen J.E. 2000 European Journal of Agronomy. 13:65–82
[15] Stolze M, Piorr A, Harring A, and Dabbert S. 2002 Economics and Policy. Vol 6. University of Hohenheim, Germany
[16] Hasegawa H, Furukawa Y, and Kimura SD. 2005 Agriculture, Ecosystems and Environment. 108:350-362.
[17] Fenning JO, T Adjie Gyapong, E Yeboah, EO Ampontuah, and G Wuansah 2005 Journal of sustainable Agriculture. 25 (4): 69 – 92
[18] Yang C, Yang L, Yang Y, and Ouyang Z. 2004 Agricultural Water Management. 70: 67-81
[19] Sukristiyonubowo and E Tuherkhi. 2009 Jurnal Penelitian Pertanian Tanaman Pangan. 28(3): 139-147
[20] Soil Research Institute. 2009. Penuntun analisa kimia tanah, tanaman, air dan pupuk (Procedure to measure soil chemical, plant, water and fertilizer). Soil Research Institute, Bogor. 234 p. (in Indonesian).
[21] Syukur A. 2005. Soil Science and Environment Journal. Vol. 5 (1); p.30-38
[22] Sommerfeldt TG, Chang C, and Entz T. 1988 Soil Science Society of America Journal. 52: p. 1668-1672.
[23] Clark MS, Horwath WR, Shennan C, and Scow KM. 1998 Agronomy Journal. 90: p.662-671.
[24] Rasmussen PE and Parton WJ. 1994. Long-term effects of residue management in wheat-fallow: I. Inputs, yields, and soil organic matter. Soil Science Society of America Journal. 58:523-530.
[25] Wander MM, Traina SJ, Stinner BR, and Peters SE. 1994 Soil Science Society of America Journal. 58: 1130-1139
[26] Mandal, Uttam K, Singh G, Victor US, and Sharma KL. 2003. Green Manuring: its effect on soil properties and crop growth under rice-wheat cropping system. European Journal of Agronomy. 19: 225-237
[27] Pirngadi K. 2009. The Contribution of Organic Matter on Increasing Rice Yield to support Sustainable Agriculture and National Food Security. Journal of Agricultural Innovation Development. 2(1):48-64.