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Improvement of Physical and Chemical Soil Quality of Oil Palm Plantation through Integrated Farming System of Cattle and Oil Palm to Achieve Sustainable Agriculture

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ABSTRACT

The objectives of the research were to compare the quality of physical and chemical characteristics of the soils in the oil palm plantations applied with integrated farming system of cattle and oil palm plantation (IFSCO) and without IFSCO (non-IFSCO), as well as to evaluate the economic benefits of IFSCO application. The research was conducted in two oil palm plantations, *i.e.* an oil palm plantation applied with IFSCO (5 ha) and an oil palm plantation without IFSCO application (non-IFSCO) (5 ha), located in the Karya Makmur Village, Penawar Aji Subdistrict, Tulang Bawang District, Lampung, Indonesia, in June until August 2016. The research was conducted using a survey and systematic sampling methods to collect soil samples, and data from 30 farmers who applied IFSCO and other 30 farmers who applied non-IFSCO. The results showed that the application of organic fertilizer in the IFSCO field resulted in higher level of exchangeable-K, -Ca, -Mg, and -Na, cation exchange capacity (CEC), and organic-C content of the soil;and better improvement on the physical soil quality, *i.e.* bulk density, porosity and soil moisture content; in comparison to that in the field without organic fertilizer application (non-IFSCO field). However, the application of IFSCO did not affect the pH, available-P, base saturation and total-N content of the soil. There was a difference in the texture class of the soils in the IFSCO field and non-IFSCO field. The result of texture analysis showed that the texture of the soil in the IFSCO field is “clay”, while the texture of the soil in the non-IFSCO field is “sandy clay loam”. Application of IFSCO can save the fertilizer cost by 66%, the feed cost by 50%, and can increase oil palm production and farmers’ income by about 25%, so it is economically profitable. Thus, IFSCO can improve soil quality and provide economic benefits for the farmers, so the IFSCO obviously supports the implementation of sustainable agriculture.

Keywords: Integrated farming system, production efficiency, soil properties, sustainable agriculture

ABSTRAK

Tujuan penelitian ini adalah untuk membandingkan kualitas tanah, baik fisik maupun kimia tanah pada lahan SISK dan lahan yang tidak menerapkan SISK (Non-SISK) serta mengetahui manfaat ekonomi (efisiensi biaya produksi) dari penerapan SISK tersebut. Penelitian dilakukan dari bulan Juni-Agustus 2016, pada 2 (dua) areal perkebunan kelapa sawit, yaitu Lahan SISK (5 ha) dan lahan Non-SISK (5 ha) yang berada di Kampung Karya Makmur, Kecamatan Penawar Aji, Kabupaten Tulang Bawang dengan menggunakan metode survei dan *systematic sampling* untuk pengambilan contoh tanah serta wawancara terhadap petani/peternak yang menerapkan integrasi (SISK) maupun yang tidak (Non-SISK). Hasil penelitian menunjukkan bahwa pemberian pupuk organik pada lahan SISK berpengaruh nyata terhadap peningkatan kadar K-dd, Ca-dd, Mg-dd, Na-dd, KTK, C-Organik dan memperbaiki kualitas sifat fisika tanah (*bulk density*, ruang pori total, tekstur, dan kadar air) dibandingkan dengan lahan tanpa aplikasi pupuk organik (Non-SISK). Namun, SISK tidak berpengaruh nyata terhadap kadar pH, P-tersedia, kejenuhan basa dan N-total. Terdapat perbedaan kelas tekstur tanah antara lahan SISK dan Non-SISK. Hasil analisis tekstur menunjukkan bahwa kelas tektur tanah pada lahan SISK adalah ”liat” sedangkan lahan Non-SISK bertekstur “lempung liat berpasir”. Penerapan SISK dapat menghemat biaya pembelian pupuk sebesar 66%, biaya pembelian pakan ternak sebesar 50% dan dapat meningkatkan produksi kelapa sawit serta pendapatan petani sekitar 25%, sehingga menguntungkan secara ekonomi. SISK dapat memperbaiki kualitas tanah dan menguntungkan secara ekonomi, sehingga dapat mewujudkan pertanian berkelanjutan.

Kata Kunci: Efisiensi produksi, sifat-sifat tanah, sistem pertanian terpadu, pertanian berkelanjutan

INTRODUCTION

An increase of agricultural food consumption has lead to an increase of intensive agricultural practices. This phenomenon can cause degradation of physical, chemical and biological soil quality unless a proper soil management is applied. Therefore, efforts to improve soil quality, especially the physical and chemical soil quality, are needed for a long term, so that a sustainable agriculture can be achieved.

Sustainable agriculture is an integrated agricultural management system that can improve productivity of land gradually, maintain a wholeness and diversity of ecology and natural resources for a long term, provide economic benefits to society, contribute on quality of life, and strengthen the economic development of a country.

Up to now, farmers depend largely on the use of chemical fertilizers to sustain their agricultural productions although an excessive chemical fertilizer use without adding organic fertilizers and applying soil consevation practices would lead to a decrease of soil productivity. This phenomenon is in line with the study of Dinata (2012), Dharmayanti *et al.* (2013), Uphoff (2006) and Lestari (2009), which showed that application of inorganic fertilizers continually would lead to a decrease of soil quality.

One way to restore agricultural soil fertility is via application of organic fertilizers. Organic fertilizers can be produced from cattle manure, which has not been used intensively by the farmers. The study of Kaya (2014) indicated that the use of manure can increase soil pH and available-K. In addition, application of manure can increase soil organic-C and organic–N contents and soil cation exchange capacity (Adimihardja *et al.* 2000), and improve soil bulk density and porosity (Margolang *et al.* 2015).

The study of Priyanti *et al.* (2008) suggested that a decrease of soil fertility due to low level of soil organic matter content can be overcomed concurrently by applying an integrated farming system of plants and cattle using a Low External Input Sustainable Agriculture (LEISA) approach, especially for the area with the development of cattle farming. The study of Haryanto (2009) showed that an Integrated Farming System of Plants and Cattle can create a condition of “zero waste – zero cost”, which is efficient for the farmers and friendly for the environment. Therefore, cattle farming can probably be integrated with oil palm plantation.

The concept of integrated farming system of cattle and oil palm plantation is expected to give synergetic benefits, which come from plants, cattle and interaction of both plants and cattle. Oil palm plants get the nutrients from the application of cattle manure and on the other hand, cattle get their feed from the waste of oil palm plants (Kementan 2011). The study of Slade *et al.* (2014) indicated that an integrated farming system of cattle and plants via cattle grazing on oil palm plantation in SMART Research Institute (SMARTRI) in Riau Province, Indonesia, resulted in positif effects on soil nutrient availability, soil structure, water infiltration, soil porosity, and soil moisture.

The integrated farming system of cattle and oil palm plantation (IFSCO) gives more benefit than intensive farming system (conventional farming) because the cost for the inputs, such as fertilizers and feeds, can be reduced, resulting in an efficient farming system. The study of Kariyasa (2005) showed that an integrated farming system of rice and cattle can save the cost for fertilizers 18.14% up to 19.48%. In addition, the study of Novra (2011) suggested that application of 1 Mg of compost of cattle manure is similar to that of 19.2 kg urea, 10.86 kg TSP and 92.52 KCl, and application of cattle manure can subtitute inorganic fertilizer application for five oil palm plants, so that the cost to buy inorganic fertililzers can be saved.

The practice of IFSCO has not been applied widely by the farmers in Tulang Bawang District, Lampung Province, Indonesia. The data collected from a survei showed that about 65 out of 518 farmers in Tunas Karya Village and Karya Makmur Village, Penawar Aji Subdistrict, Tulang Bawang District has applied the IFSCO (Disnak dan Keswan 2016). Karya Makmur Village is a potential place in Tulang Bawang District for the development of cattle farming and oil palm plantation. However, up to now the IFSCO has not been fully applied by the farmers in Karya Makmur Village. The practice of IFSCO has been applied only for a specific purpose, *i.e.* feed supply, without considering the potential impact of IFSCO on the quality of agricultural land. Most of the farmers have not been convinced by the positive effects of use of cattle manure on the improvement of soil quality and efficiency of production cost.

The study aims to compare the quality of soil, both physical and chemical soil quality, at oil palm plantation applied with IFSCO and without IFSCO (non-IFSCO), and to study the economic benefit of IFSCO (*i.e.* efficiency of cost production) to achieve sustainable agriculture. The practice is expected to be able to educate farmers at Karya Makmur Village and probably farmers at other locations to contribute on the implementation of sustainable agricultural system.

MATERIALS AND METHODS

Location of the Study

The research was conducted in June until August 2016 at the area for the development of cattle farming, *i.e.* Karya Makmur Village, Penawar Aji Subdistrict, Tulang Bawang District, Lampung Province, Indonesia. The study was conducted in two oil palm plantations, *i.e.* an oil palm plantation applied with IFSCO (about 5 ha) and a conventional oil palm plantation without IFSCO application (non-IFSCO) (about 5 ha). The map of study site is presented in Figure 1.

The IFSCO has been applied at the study site since the beginning of 2015 (at the 4th year old of oil palm plants), so up to now the IFSCO has been applied for 1.5 years. When the study was conducted, the age of oil palm plants at the study site with and without IFSCOapplications were about 5.5 years old and the plants have delivered yields for 1.5 years.

The oil palm plants in the field applied with IFSCO were fertilized with organic fertilizer (10 kg plant^{-1} or 1.25 Mg ha^{-1}) produced from Organic Fertilizer Processing Unit, dolomite (1 kg plant^{-1} or 125 kg ha^{-1}), and inorganic fertilizers (Urea 100 kg ha^{-1}, SP-36 50 kg ha^{-1}, and KCl 50 kg ha^{-1}). The fertilizers were applied once a year. On the other hand, in the field without IFSCO application, the oil palm plants were not fertilized with organic fertilizer. The plants were only fertilized with ionrganic fertilizers, *i.e.* Urea 150 kg ha^{-1}, SP-36 75 kg ha^{-1}, and KCl 75 kg ha^{-1} for each application. The inorganic fertilizers were applied twice a year.

Equipment and Materials

The equipment used in the study were Global Positioning System (GPS), soil ring sampler, soil auger, balance, *Barlese* funnel, sieve, test tubes, petridish, pipette, *ose* needles, incubator, autoclave, microscope, camera, laptop and other laboratorial equipment. The materials used in the study were disturbed soil samples and undisturbed soil samples for soil chemical and soil physical analyses, respectively. In addition, a questionnaire was used during the interview with the farmers to collect the data about economic benefits of IFSCO.

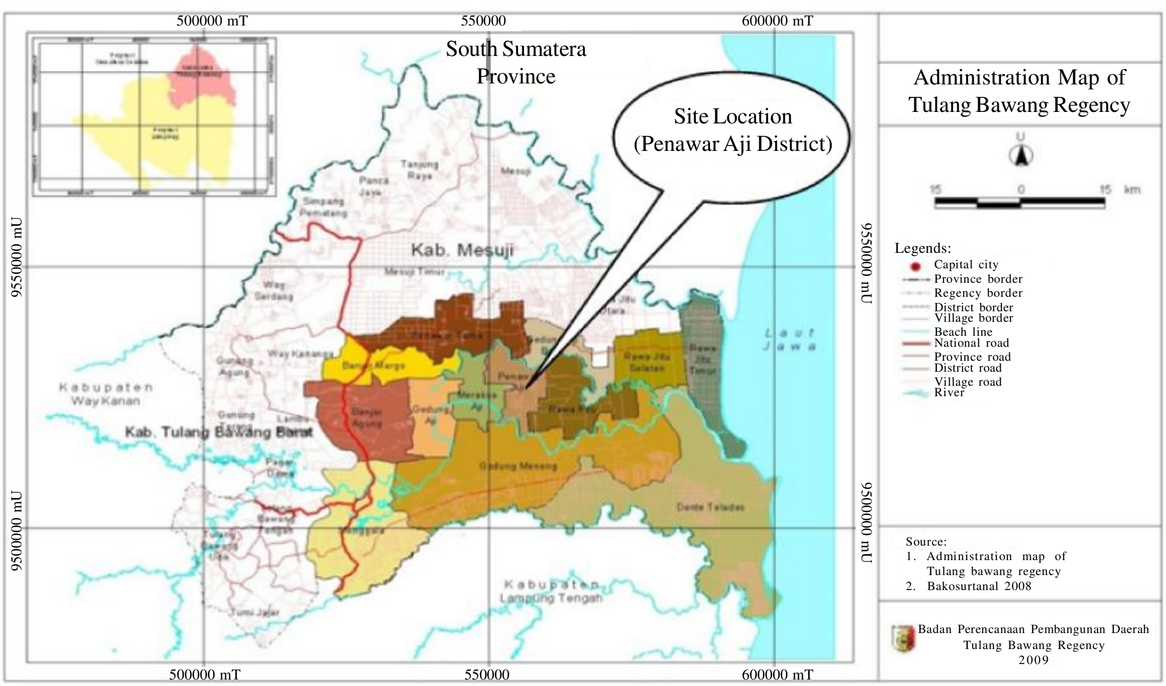

Figure 1. The map of the location of the study. Location of the study: Penawar Aji Subdistrict, Lampung, Indonesia.

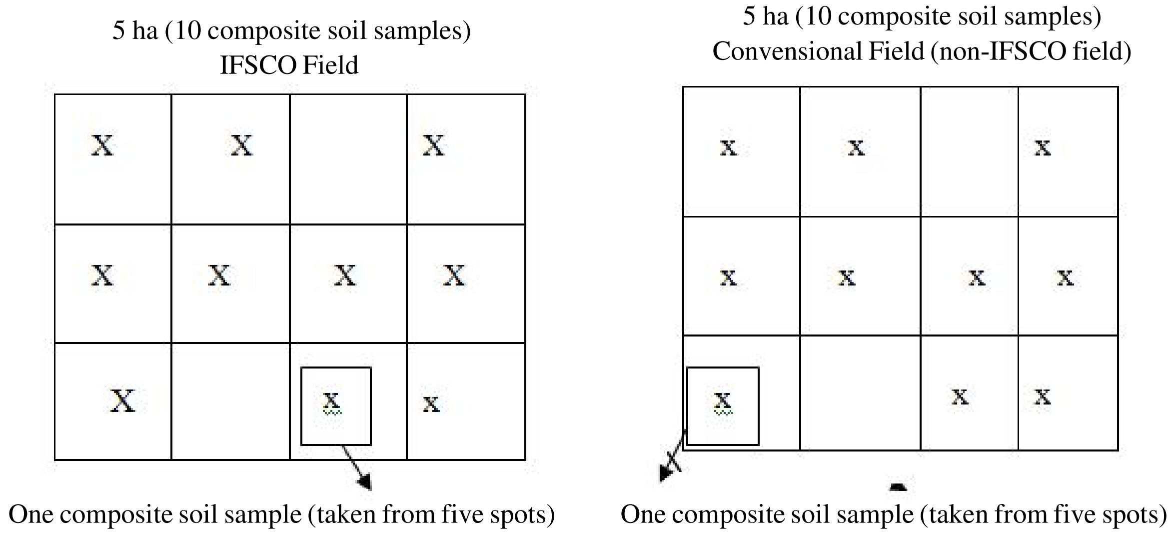

Figure 2. The scheme of spots for soil sampling in the IFSCO field and non-IFSCO field using systematic sampling method (Suganda *et al.* 2006).

Research Methods

The study was conducted using survey and systematic sampling methods to collect soil samples, and data from 30 farmers who applied IFSCO and other 30 farmers who applied non-IFSCO. The physical and chemical properties of soil samples including bulk density, porosity, texture, moisture content, pH, available-P, exchangeable-K, -Ca, -Mg, and –Na, cation exchange capacity, base saturation, total-N, and organic-C content were analyzed.

Both undisturbed soil samples and disturbed soil samples for physical and chemical soil analyses, respectively, were taken in each field with IFSCO application (5 ha) and field without IFSCO application (non-IFSCO, 5 ha). Disturbed soil samples were taken at the top soil 0-20 cm using an auger, while undisturbed soil samples were taken using soil ring samplers. In each field, the soil samples were taken systematically from 10 spots, with the distance between one spot to another spot was 60-100 m (Figure 2). The soil analysis was conducted at the Laboratory of Soil Science, Faculty of Agriculture, University of Lampung.

Data Analysis

The data analysis was performed by comparing the physical and chemical characteristics of soil samples of both fields (field with IFSCO application and field without IFSCO application) with the criteria of soil physical and chemical characteristics proposed by Balittanah (2009). Further, a statistical analysis was performed on the data using t-test using Minitab 16 software.

The data resulted from the interview with 60 farmers were used to study the economic benefits of IFSCO for farmers, including efficiency of production cost and income of the farmers after applying the IFSCO. The data were analyzed by comparing the average of production cost efficiency, which includes cost for fertilizers and feeds, and income of the farmers who applied IFSCO and non-IFSCO.

RESULTS AND DISCUSSION

Chemical Characteristics of the Soils at the Oil Palm Plantations

Based on the criteria of soil characteristics proposed by Balittanah (2009), the chemical characteristics of the soil in the oil palm plantation applied with IFSCO are in the category of very low up to high, while the soil chemical characteristics in the oil palm plantation without IFSCO application (non-IFSCO) are in the category of very low up to moderate. The results of t-test on the soil chemical characteristics are presented in Table 1. The values of each soil parameter presented in the Table 1 are the average values of 10 soil samples taken in the field with IFSCO application or 10 soil samples taken in the field without IFSCO application.

Table 1 showed that the application of organic fertilizer on the field with IFSCO application significantly increased the content of exchangeable-K, -Ca, -Mg, and –Na; cation exchange capacity; available-P, base saturation, and total-N of the soil.

The average pH of the soil in the field with IFSCO application is 3.81, and the soil pH in the

Table 1. The results of t-test on soil chemical properties in the IFSCO field and non-IFSCO field.

Soil chemical properties	Results of soil analysis (average ± standard deviation)		Results of t-test	
	IFSCO field	Non-IFSCO field	p-value	t-value
pH	3.81 $_{\pm 0.27}$	3.83 $_{\pm 0.25}$	0.865	-0.17
Available-P (ppm)	4.35 $_{\pm 5.07}$	2.92 $_{\pm 0.25}$	0.418	0.83
Exchangeable-K (me 100 g^{-1})	0.17 $_{\pm 0.12}$	0.09 $_{\pm 0.03}$	0.038*	2.24
Exchangeable-Ca (me 100 g^{-1})	0.87 $_{\pm 0.23}$	0.35 $_{\pm 0.37}$	0.001*	3.77
Exchangeable-Mg (me 100 g^{-1})	0.26 $_{\pm 0.12}$	0.12 $_{\pm 0.08}$	0.008*	2.97
Exchangeable-Na (me 100 g^{-1})	0.06 $_{\pm 0.01}$	0.04 $_{\pm 0.02}$	0.023*	2.48
CEC (me 100 g^{-1})	11.16 $_{\pm 1.19}$	7.82 $_{\pm 2.99}$	0.004*	3.27
Saturation base (%)	11.89 $_{\pm 3.68}$	7.67 $_{\pm 5.64}$	0.063	1.98
Total-N (%)	0.20 $_{\pm 0.05}$	0.15 $_{\pm 0.07}$	0.062	1.99
Organic-C (%)	3.90 $_{\pm 0.63}$	2.99 $_{\pm 0.88}$	0.017*	2.63

Note: *significantly different at 5% siginificance level.

field without IFSCO application is 3.83. Based on the criteria of soil characteristics proposed by Balittanah (2009), both pHs are categorized as very acid.The very low soil pH in both fields is probably due to the high amount of organic matter that has not been decomposed and the very low content of Ca and Mg in the soils in both fields. During the research period, the organic fertilizer has been applied for 1.5 years, so the decomposition and mineralization processes of organic fertilizer may still happen. The decomposed organic materials contain reactive groups, such as carboxylic (-COOH) and phenolic (C_6H_4OH), which dominate the exchange sites and present as weak acids, so they can dissociate and further contribute a certain amount of hydrogen ion (H^+) into soil solution. This phenomenon corresponds to the study of Hartatik *et al.* (2006), which suggested that the decrease of soil pH after application of organic fertilizer is due to the decomposition process of organic materials that produce organic acids.

The content of available-P in the soils from field applied with IFSCO is not significantly different from that in the non-IFSCO field, however, the available-P in the IFSCO field is in the category of low, while in the non-IFSCO field the available P is very low. The different content of available-P in both fields may be due to the addition of organic fertilizer in the IFSCO field. At very acid pH, the amount of soluble Al and Fe in the soil increases and both Al and Fe can bind P, resulting in a very low amount of available-P in the soil from non-IFSCO field. On the other hand, by adding organic fertilizer that contains 0.352% total-P in the IFSCO field, there will be a contribution of P from mineralization of organic fertilizer, resulting in an increase of the amount of available P in the soil. In addition, application of organic fertilizer helps to release P in the form of soluble phosphate (PO_4^{3-}) that is previously bound by Al and Fe. This phenomenon is in line with the study of Stevenson (1982), which suggested that the amount of available-P in the soil can be increased by adding organic materials.

The content of exchangeable-K in the soil of IFSCO field is about 0.17 me 100 g^{-1} (category: low), which is significantly different from that in the non-IFSCO field, *i.e.* 0.09 me 100 g^{-1} (category: very low). The result suggested that addition of organic fertilizer resulted in an increase of the amount of exchangeable-K in the soil. The very low amount of exchangeable-K in the soils of the current study sites is probably due to the very acid pH, which leads to the leaching of K from the soil. As a result, the content of exchangeable-K in the soil of non-IFSCO field is very low. In contrast, the addition of organic fertilizer in the IFSCO field increased the amount of exchangeable-K in the soil. This phenomenon is due to the addition of K derived from organic fertilizer applied, which contains 1.459% K. The results of current study correspond to the study of Kaya (2014) and Hanifa and Lutojo (2014) that showed that application of organic fertilizer significantly affect the content of exchangeable-K in the soil, which creates a better nutrient balance in the soil.

The amount of exchangeable-Ca in the soil of IFSCO field is significantly different from that in the non-IFSCO field. In general, the amount of exchangeable-Ca in the IFSCO field is higher than that in non-IFSCO field, although both amounts are in the category of very low according to the criteria proposed by Balittanah (2009). The low amount of exchangeable-Ca in the soils is due to the very acid soil, which leads to the leaching of Ca following the percolating water that further brings the Ca into the subsoil horizons.

The difference in the content of exchangeable-Ca in the soils of the IFSCO field and non-IFSCO field is due the addition of organic material in the IFSCO field, so the Ca that is previously bound to P would be dissociated as soluble Ca-complex compound. As a result, the amount of exchangeable-Ca in the soil of IFSCO field is higher than that in the non-IFSCO field. However, since the amount of organic fertilizer applied to the soil is low (*i.e.* 10 kg or 1.25 Mg ha^{-1} yr^{-1}) and the organic fertilizer has just been applied for 1.5 years, the content of exchangeable-Ca in the soil of IFSCO field is still in the category of very low (< 2 me $100g^{-1}$).The result of current study is in line with the study of Santoso *et al.* (2015) that indicated that application of compost on the oil palm seedling plantations can increase the plant uptake of N, P, K, Ca and Mg about 18.8%, 24.0%, 17.04%, 15.8% and 13.6%, respectively, in comparison to that in the control plot (without compost application).

Similar to the content of exchangeable-Ca, the content of exchangeable-Mg in the soil of IFSCO field is significantly different from that in non-IFSCO field. The average of exchangeable-Mg content in the IFSCO field is 0.26 me 100 g^{-1} or a bit higher than that in the non-IFSCO field (*i.e.* 0.12 me 100 g^{-1}), however, both amounts are in the category of very low. This result is due to the very acid soil, which leads to the leaching of Mg following the percolating water that further brings the Mg into the subsoil horizons.Addition of organic fertilizer in the IFSCO field increased the amount of exchangeable-Mg in the soil. This phenomenon is due to the organic acids resulted from the organic matter decomposition can bind the exchangeable-Mg, as a result the exchangeable-Mg will not be leached out from the soil, but the Mg will form a complex compound that would be available for plant uptake. However, due to the amount of organic fertilizer applied to the soil in the IFSCO field is low and the organic fertilizer has just been applied for 1.5 years, the content of exchangeable-Mg in the IFSCO field is still in the category of very low.

The result of t-test showed that the content of exchangeable-Na in the soil of IFSCO field is significantly different ($p < 0.05$) from that in the non-IFSCO field. The content of exchangeable-Na in the IFSCO field is higher than that in the non-IFSCO field, however, the content of exchangeable-Na in the soils of both fields is in the category of very low according to the criteria of soil characteristics proposed by Balittanah (2009).This result is due to the exchangeable-Na is easily leached out following the percolating water that further brings the Na into the subsoil horizons. The study of Adiwiganda (1998) suggested that the low content of exchangeable cations in the soil (Ca^{2+}, Na^{+}, and K^{+}) is due to the soil predominantly contains low activity of colloidal clay.

The average cation exchange capacity (CEC) of the soil in the IFSCO field is 11.6 me 100 g^{-1}, which is higher than that in the non-IFSCO field (7.82 me 100 g^{-1}), however, both CECs are in the category of low. The result of t-test showed that the CEC of the soil in the IFSCO field is significantly different from that in the non-IFSCO field. The results suggested that application of organic fertilizer on the IFSCO field increased the soil CEC about 3.3 me 100 g^{-1}. This phenomenon is probably due to the reactive groups of –COOH and –OH in the organic materials lead to an increase of cation exchange, which further increases the soil CEC.The low CEC of the soil in the non-IFSCO field corresponds to the study of Arifin (2003), which indicated that application of inorganic fertilizers continuously would result in negative effects on the soil, including the decrease of soil organic matter content and soil CEC and unbalanced nutrient content.

The average base saturation of the soil in the IFSCO field is 11.89%, which is higher than that in the non-IFSCO field (*i.e.* 7.67%), however, the soil base saturations in both fields are in the category of very low. This result is in line with the result of t-test, which showed that the application of organic matter on the IFSCO field shows no significant effect on the soil base saturation. This condition may be due to the low dosage of organic fertilizer applied on the IFSCO field and the organic fertilizer has just been applied for 1.5 years, therefore, its effect to the increase of soil base saturation is not significant.

Although the soil base saturation in both fields are very low, the application of organic fertilizer on the IFSCO field has increased the soil base saturation obviously compared to that in the non-IFSCO field. This result corresponds to the study of Minardi *et al.* (2014) that indicated that application of organic fertilizer (*i.e.* manure) and inorganic fertilizer with the ratio of 75%:25% increased the soil base saturation from 20% to 31.67%, compared to that in the control treatment.

The total-N content of the soil in the IFSCO field is 0.20%, which is higher than that in the non-IFSCO field, *i.e.* 0.15%, however, both values are in the category of low with the range of 0.10% –

Table 2. The results of t-test on the soil physical properties in the IFSCO field and non-IFSCO field.

Soil physical properties	Results of soil analysis (average ± standard deviation)		Results of t-test	
	IFSCO field	Non-IFSCO field	p-value	t-value
Bulk density (g cm^{-3})	0.84 $_{\pm 0.11}$	0.57 $_{\pm 0.21}$	0.005*	3.43
Porosity (%)	68.46 $_{\pm 4.28}$	78.41 $_{\pm 8.15}$	0.003*	-3.45
Moisture content (%)	23.4 $_{\pm 2.76}$	32.4 $_{\pm 9.80}$	0.012*	-2.80
Soil Texture:				
- Sand (%)	39.74	57.64		
- Silt (%)	7.58	11.84		
- Clay (%)	52.69	30.53		

Note: *significantly different at 5% siginificance level

0.20%. The result of t-test showed that the application of organic fertilizer on the IFSCO field shows no significantl effect ($p > 0.05$) on the total-N content of the soil. This phenomenon is probably due to the low amount of organic fertilizer applied in the IFSCO field and the organic fertilizer has just been applied for 1.5 years, so the decomposition and mineralization processes of organic fertilizer may still happen. However, the application of organic fertilizer, which contains the average total-N 1.213%, increased the total-N content of the soil in the IFSCO field up to 0.055%, compared to that in the non-IFSCO field. The results of current study are in line with the study of Hasibuan (2006) that suggested that other sources of N in soil are rain water and fertilizers. The study of Jamilah (2003) indicated that manure contains N, therefore, an increase dosage of organic fertilizer applied would increase the soil total-N.

The average content of soil organic-C in the IFSCO field is 3.90% (category: high), while in the non-IFSCO field, the soil organic-C content is 2.99% (category: moderate). This result corresponds to the result of t-test, which showed that the organic-C content in the soil of IFSCO field is significantly different ($p < 0.05$) from that in non-IFSCO field. This condition is probably due to the addition of organic-C derived from organic fertilizer applied to the soil of IFSCO field in which the fertilizer contains 2.15% organic-C. As a result, the content of organic-C in the soil of IFSCO field increased about 0.90% compared to that in the non-IFSCO field. The study of Adimihardja *et al.* (2000) indicated that the application of several manures, namely cow manure, goat manure and chicken manure with the dosage of 5 Mg ha^{-1} to the Ultisol increased significantly soil organic-C content and production of corn and soybean.

Physical Characteristics of the Soils at the Oil Palm Plantations

Table 2 indicated that application of organic fertilizer on the IFSCO field significantly affected bulk density, porosity, and soil moisture content of the soil. The soil texture in the IFSCO field is different from that in the non-IFSCO field. The soil in the IFSCO field is dominated by clay fraction (52.69%), whereas the soil in the non-IFSCO field is dominated by sand fraction (57.64%). The results of soil textural triangle analysis showed that the soil texture in the IFSCO field is clay, while the soil texture in the non-IFSCO field is sandy clay loam.

The average soil bulk density in the IFSCO field is 0.84 g cm^{-3}, which is higher than that in the non-IFSCO field, *i.e.* 0.57 g cm^{-3}. The result of t-test showed that the soil bulk density in the IFSCO field is significantly different from that in the non-IFSCO field.

The soil bulk density is influenced by soil texture, structure and organic matter content. In general, the mineral soil contains 1% - 9% organic-C (Fadhilah 2010) with the bulk density of 1.0 – 1.6 g cm^{-3} (Hardjowigeno 2003). In contrast, the soils in the study site have moderate up to high organic matter contents, so the application of organic fertilizer results in a soil bulk density that is different from the common soil bulk density found for mineral soils.

The soils in the study site have a very low bulk density, which is below the average bulk density of mineral soils in general. This phenomenon is due to the soil organic matter content in both IFSCO field and non-IFSCO field is relatively high for mineral soils, which further results in high soil porosity and soil moisture content. The texture of the soil in the IFSCO field is clay, so the bulk density of this soil is higher than the sandy clay loam soil in the non-IFSCO field. Application of organic fertilizer has improved the soil structure in the IFSCO field. As a result, without application of organic fertilizer, the soil bulk density in the non-IFSCO field is about 0.57 g cm^{-3}, whereas application of organic fertilizer in the IFSCO field has improved the soil structure via soil particles aggregation, therefore, the soil bulk density of the IFSCO field has increased into 0.84 g cm^{-3}. This value is close to 1 g cm^{-3}, which is in the normal range of bulk density for mineral soils and for an optimum plant growth.

The values of soil porosity are inversely proportional to the values of soil bulk density. Table 2 showed that the average soil porosity in the IFSCO field is about 68.46%, which is lower than that in the non-IFSCO field with the soil porosity of 78.41%. The result of t-test indicated that the soil porosity in the IFSCO field is significantly different from that in the non-IFSCO field. The result suggested that application of organic fertilizer significantly affected the soil porosity in the IFSCO field.

The soil porosity is influenced by soil texture, structure and organic matter content. The soil in the IFSCO field, which contains mainly clay fraction (soil texture: clay), is dominated by micro pores, resulting in a lower soil porosity than that in the soil of non-IFSCO field that contains mainly sand fraction (dominated by macro pores). In addition, the lower soil porosity in the IFSCO field compared to that in the non-IFSCO field is caused by the addition of organic fertilizer in the IFSCO field. Hardjowigeno (2003) suggested that the function of organic materials, among others, is to improve the soil structure. Since the soil in the study site is very porous with the soil porosity of 60% up to 80%,the addition of organic fertilizer therefore would fill in partly the total soil pores and bind the soil particles. As a result, the soil porosity in the IFSCO field decreases and leads to lower soil porosity than that in the non-IFSCO field. However, this condition is good for soil to create a better granular structure, which leads to a better nutrient uptake and further influences the growth of oil palm plants.

Table 2 showed that the average soil moisture content in the IFSCO field is 23.4%, which is lower than that in the non-IFSCO field, *i.e.* 32.4%. The result of t-test indicated that the soil moisture content in the IFSCO field is significantly different from that in the non-IFSCO field. This result is in line with the data of soil porosity. The soil porosity in the IFSCO field, which is applied with organic fertilizer, is lower than that in the non-IFSCO field because the organic material can bind the soil particles and fill in partly the total soil pores, as a result the number of soil pores that can be filled in by water decreases and the soil moisture content in the IFSCO field becomes lower than that in the non-IFSCO field. In addition, no "slit pit" (*rorak*) was built in the non-IFSCO field, which is in contrast to that in the IFSCO field. As a result, the soil surface in the non-IFSCO field would be saturated by the water during rainy season. The "slit pit" (*rorak*) can collect and store the excess of surface water into the soil during rainy season, so the infiltration and the availability of water in the soil would increase during dry season. The study of Murtilaksono *et al.* (2008) indicated that "slit pit" (*rorak*) and "discontinued ditch" help to store the excess of surface water during rainy season and provide water during dry season.

The results of soil physical and chemical analyses showed that the quality of the soil in the IFSCO field is in general better than that in the non-IFSCO field. This result is supported by the fact that the appearance of oil palm plants in the IFSCO field is better than that in the non-IFSCO field, which

(a) (b) (c) (d)

Figure 3. The appearance of oil palm plants and their fruits: (a) and (b) in the IFSCO field; (c) and (d) in the non-IFSCO field (author's photo collection 2016).

includes the more perpendiculare plants, the greener leaves, the brighter and more lustrous of oil palm fruits, and the bigger size of oil palm fruits (Figure 3). In addition, the difference in the soil quality can also be indicated by the production of oil palm plants.The results of interview with the farmers showed that the average oil palm production in the IFSCO field is 18 Mg ha^{-1} yr^{-1}, while the oil palm production in the non-IFSCO field is 14 Mg ha^{-1} yr^{-1}. This result suggested that the IFSCO application can improve soil quality and support the sustainable agriculture program.

Economic Benefits of Integrated Farming System of Cattle and Oil Palm Plantation

The result of interview with 60 farmers (*i.e.* 30 farmers who apply IFSCO and 30 farmers who do not apply IFSCO) showing the economic benefits of IFSCO application is presented in Table 3.

The results of interview (Table 3) showed that the cattle farming produces manure on average 10 kg cow^{-1} or 3,650 kg cow^{-1} yr^{-1}. Oil palm plantation produces solid waste, *i.e.* 40 stems $plant^{-1}$ yr^{-1} or 5,000 stems ha^{-1} (the number of plants per ha is 125). If the weight of each stem is ± 4 kg, the total waste produced by oil palm plantation is 20,000 kg yr^{-1}.

The farmers who apply IFSCO have turned the manure waste into organic fertilizer, and each cow can produce dried organic fertilizer 1,095 kg cow^{-1} yr^{-1}. If the average cost of organic fertilizer is 850 rupiahs kg^{-1}, the farmers can get additional income from the organic fertilizer about 930,750 rupiahs cow^{-1} yr^{-1}. In addition, the farmers who apply IFSCO can get the benefits from the use of waste of oil palm stems for making silage. The amount of stems produced for one ha is about 20,000 kg ha^{-1} yr^{-1}. This amount is enough to provide green feed for 4 cattle. If the number of cattle owned by the farmers is less than 4 cattle, the excess of silage made from oil palm stems can be used as another source of income for farmers. In contrast to the farmers who do not apply the IFSCO, the manure waste and oil palm stems are no use, as a result no additional economic benefits can be gained from their plantations.

In the IFSCO field, the farmers use the organic fertilizer, so the dosages of inorganic fertilizer can be reduced into 100 kg Urea ha^{-1}, 50 kg TSP ha^{-1}, 50 kg KCl ha^{-1} and 125 kg dolomite ha^{-1}, with the total fertilizer cost of 755,000 rupiahs ha^{-1}. On the other hand, the farmers who do not apply IFSCO do not apply organic fertilizer, as a result the dosages of inorganic fertilizers applied are higher than the dosages used by the farmers who apply IFSCO. The results of interview showed that the average dosages of inorganic fertilizers applied on the non-IFSCO field are 300 kg Urea ha^{-1}, 150 kg TSP ha^{-1}, 150 kg KCl ha^{-1} and 126 kg dolomite ha^{-1}, which applied two times in a year. In general, the application of IFSCO can save the cost to buy fertilizer about 1,435,000 rupiahs ha^{-1} or 66% of the total fertilizer cost in the non-IFSCO field. This result corresponds to the study of Kariyasa (2005) that indicated that application of manure in the integrated farming system of rice and cattle has saved the fertilizer cost about 18.14% up to 19.48% or about 8.8% of total production cost.

In addition, farmers who apply IFSCO can save the feed cost because the farmers have reused the oil palm stems to supply green feed for the cattle. This result is in line with the study of Elisabeth and Ginting (2003), which suggested that the oil palm stems can be used as green feed to subtitute grass for cattle. With the application of IFSCO, the farmers just need to supply the feed in the form of concentrates, such as rice husks, fermented cassava waste, and cassava peels with the average total cost of 600,000 rupiahs cow^{-1} yr^{-1}. On the other hand, the farmers who do not apply IFSCO use grass or a

Table 3. The results of interview (presented as average values) with the farmers who apply IFSCO and non-IFSCO in Karya Makmur Village, Aji Penawar Subdictrict, Lampung, Indonesia.

Description	IFSCO field	Non-IFSCO field	Efficiency
Manure production (kg cow^{-1} yr^{-1})	3,650	3,650	
Organic fertilizer production (kg cow^{-1} yr^{-1})	1,095	0	
Income from organic fertilizer production (rupiahs cow^{-1} yr^{-1})	930,750	0	
Cost of Inorganic fertilizers (rupiahs ha^{-1})	755,000	2,190,000	1,435,000
Oil palm waste production (kg ha^{-1} yr^{-1})	20,000	0	
Feed cost (rupiahs cow^{-1} yr^{-1})	600,000	1,200,000	600,000
Oil palm production (Mg ha^{-1} yr^{-1})	18	14.4	
Total income (rupiahs ha^{-1} yr^{-1})	21,600,000	17,280,000	4,320,000

certain green feed to supply the green feed for cattle, so the cost to buy feed is high, *i.e.* 1,200,000 rupiahs cow^{-1} yr^{-1}. Therefore, the application of IFSCO can save the feed cost about 600,000 rupiahs cow^{-1} yr^{-1} or about 50% of the total feed cost for the non-IFSCO field.

Table 3 showed that the oil palm production in the IFSCO field is higher than that in the non-IFSCO field. The results of interview indicated that the average oil palm production in the IFSCO field is about 18,000 kg ha^{-1} yr^{-1} or 18 Mg ha^{-1} yr^{-1}, whereas the production in the non-IFSCO field is 14,400 kg ha^{-1} yr^{-1} or 14.4 Mg ha^{-1} yr^{-1}. Therefore, the application of organic fertilizer in the IFSCO field can increase the oil palm production by ± 3.6 Mg or 25%.

The application of IFSCO in general can increase the farmers' income. If the price of oil palm is 1,200 rupiahs kg^{-1}, the income of the farmers who apply IFSCO is ± 21,600,000 rupiahs ha^{-1} yr^{-1}, while the income of farmers who do not apply IFSCO is ± 17,280,000 rupiahs ha^{-1} yr^{-1}. As a result, the application of IFSCO can increase the farmers' income about 4,320,000 rupiahs ha^{-1} yr^{-1} or 25% higher compared to the income of farmers who do not apply IFSCO. In line with the results of current study, Kariyasa and Pasandaran (2004) indicated that the cultivation of rice integrated with cattle farming or use of manure in the Central Java, Bali and West Nusa Tenggara, Indonesia can produce rice 6.9% up to 8.8% higher than in the non-integrated farming system without using manure. The study of Basuni (2012) showed that the productivity of rice plants in Cianjur District, West Java, Indonesia increased about 10.29% and the use of inorganic fertilizers decreased up to 53.33% in comparison to the common cultivation system of rice applied by the farmers.

The results of interview with the farmers suggested that the application of IFSCO provided an economic benefit for farmers, namely efficiency on fertilizer cost and feed cost. The IFSCO is expected to ensure the sustainability of cattle farming and oil palm plantations in the future.

CONCLUSIONS

The soil quality in the IFSCO field is better than that in the non-IFSCO field, which is indicated by the improvement of chemical soil quality, namely exchangeable-K, -Ca, -Mg, -Na, cation exchange capacity (CEC), organic-C content; and the improvement of physical soil quality including bulk density, total porosity, soil texture, and soil moisture content. As a result, the IFSCO supports the implementation of sustainable agricultural system. In addition, the application of IFSCO can save the fertilizer cost by 66%, feed cost by 50%, and increase the oil palm production and farmers' income by 25%, so the IFSCO has provided economic benefits for farmers.

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