INNSPUB

International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 5, No. 3, p. 45-51, 2014

RESEARCH PAPER

OPEN ACCESS

Carbon sequestration and soil quality under organic system of local rice (*Oryza sativa* L.) variety in Tabanan, Bali Indonesia

I. Wayan Diara, I. Made Adnyana, I.B. Putra Manuaba, I.G.A. Mas Sri Agung*

Udayana University, Bukit Jimbaran-Badung, Bali, Indonesia

Article published on September 22, 2014

Key words: Carbon sequestration, soil quality, organic and conventional system, Rice (*Oryza sativa* L.).

Abstract

Soil organic carbon (SOC) storage has been widely considered as a measure for mitigating global climate change through C sequestration (SOCS) in soils. A study was conducted by evaluating SOC, total N, available P, K, bulk density, and total soil microbes under organic system and conventional of Local rice variety at the same time in two farmer fields (subak Jatiluwih and Wangaya Betan at Mangesta village in Penebel district,Tabanan regency, Bali Indonesia. Half of farmers in those two locations have been managing certified organic system with Red local rice variety for two years (2010-2012), while the other half maintaining conventional system. Composite soil samples were taken at three points at depth of 0-20 cm and 20-40 cm in three replications at each location. Results showed that after two years, organic system resulted in better soil quality and higher SOCS only in Jatiluwih. Significantly higher SOC (3.338%), total N (0.252%), available P (15.84 ppm), K (133.63 ppm), bulk density (0.510 Mg m^{-3}) and higher SOCS (81.354 Mg ha^{-1}) were recorded under organic compared to conventional system. In Wangaya Betan, those components, except bulk density, were not different under two systems. The yield of Red local rice variety under organic was 6.44.t ha^{-1} compared to 5.12 t ha^{-1} under conventional system.

* **Corresponding Author:** IGA Mas Sri Agung ✉ sri_agung@ymail.com

Introduction

Tabanan regency has the largest paddy fields in Bali province, Indonesia, with the production of 454288 t in 2009 or 25.91% of Bali production (1753384 t) (BPS, 2010) and has the largest farming systems of rice in Bali. Subak Jatiluwih and Wangaya Betan, which are both located in the district of Penebel, have been famous for their production of Red local rice variety. Most of this variety are cultivated under organic farming, although other farmers still maintain the conventional system .

Farmers believe that under organic system of Red local rice variety, the production will be sustainable because soil health could be sustained. Under that condition, significant improvements in soil quality (Pathak *et al.*, 1992; Carpenter *et al.*, 2000) and finally increased rice yields could be expected (Chitra and Janki, 1999).

Studies show that organic farming also improves carbon (C) sequestration potential of the soil (Booshan and Prasad, 2011). Carbon (C) sequestration is the capture and secure storage of atmospheric C into biotic and pedologic C pools (Lal, 2007). The idea of C storage is: (i) to prevent C emission caused by human activities from reaching the atmosphere by capturing and diverting it to secure storage, or (ii) to remove it from the atmosphere by various means and to enhance its mean residence time (MRT) in the soil (Olson *et al.*, 2013). The carbon in the soil has to be stored as much and long as possible, because the loss of them together with carbon dioxide resulted from rice photosynthesis, respiration and soil microbes (Pantawat, 2012) will contribute the excess of CO2 to global emissions (OECD, 2001).

Soil organic carbon, which is a very reactive, ubiquitous component in soils, is an important soil quality indicator that influences the productivity and physical well-being of soils (Blair *et al.*, 1995; Komatsuzaki and Ohta, 2007). It is important to have high potential of soil in carbon sequestration because it could contribute to greater agronomic, physiological and recovery efficiencies of nitrogen, phosphorus, and potassium (Rahman, 2013).

Soil organic carbon storage (SOCS) has been widely considered as a measure for carbon sequestration in soils (Huang *et al.*, 2010). Komatsuzaki and Syuaib (2010) found carbon sequestration of 25 Mg ha^{-1} under organic compared to 17.6 Mg ha^{-1} under conventional rice farming system in the top 10 cm depth of soil in West Java Indonesia. Minasny *et al.* (2011) also reported that continuous rice cropping has been sequestering carbon in the top 15 cm of Java soils for more than 1.7 Tg (10^{12} g) carbon during the past 30 years.

Despite of being a center of organic rice farming in Bali, there is no study has been conducted on soil carbon sequestration in the province of Bali particularly in the areas of organic rice farming system. The objective of the study was to evaluate soil carbon sequestration and soil quality under organic system of Red local rice (*Oryza sativa* L.) variety in the areas of Subak Jatiluwih and Wangaya Betan.

Materials and methods

Area of study

The study was conducted by evaluating soil carbon storage, total N, available P and K, bulk density and total soil microbes under organic and conventional system of Red local rice variety at the same time in two farmer fields (viz.subak Jatiluwih and Wangaya Betan at Mangesta village in Penebel district,Tabanan regency, Bali Indonesia) located between 115°8'0"E-115°8'30"E and 8°22'0"S-8°23'30"S. Each location was 100 ha of inceptisol and were 3.15 km apart.

The rice yield data were collected from two years farmer records. Farmers in those two locations have been managing certified organic system with Red Local rice varieties for two years. Both in Jatiluwih and Wangaya Betan, the fertilizers used by farmers in the organic system were cattle manure at 2.5 t ha^{-1}, while N-P-K-trace elements (15:15:6:4) fertilizers at 200 and 300 kg ha^{-1} were used in conventional system in those two areas. In organic system farmers used to incorporate rice straws after harvest while in conventional system the rice residues were taken out of the field. Rice in both system were harvested 180 days after transplanting. The study was carried out from October 2012 until April 2013.

Soils

Composite soil samples were taken at three points at depth of 0-20 cm and 20-40 cm in five replications at each location and were analysed in the laboratory afterwards. Soil organic carbon content (Walkley and Black method), total N (Kejldal method), texture (pipette method) bulk density (gravimetric method) and total soil microbes (pour platting method) were determined.

Soil organic carbon storage (SOCS) was calculated using the equation of Shofiyati *et al.*, 2010; Komatsuzaki and Syuaib, 2010): SOCS (Mg ha^{-1}) = BD × SOC ×DP × A, where BD is soil bulk density (Mg cm^{-3}); SOC is soil organic carbon content (%); DP is soil depth (m); A is area (ha).

Statistical analyses

Results of soil analysis were statistically analyzed based on one way randomized block design after transformation where necessary using COSTAT and MSTATC computer softwares. The means of each trait were compared according to Least significant difference at 5% (Gomez and Gomez, 1984). Figures were drawn using Excel software.

Results and discussion

Soil texture

Both locations have the same parent material of vulcanic ashes but different soil texture. The texture of soil under organic system in Jatiluwih is dominated by loam, while that in Wangaya Betan is clay-loam dominant, indicating that soil in Jatiluwih has lighter (coarser) texture than in Wangaya Betan. The texture at top 20 cm was loam indicating lighter texture while underneath layer (20-40 cm) down to hardpan has heavier (clay-loam) texture that made the particle density become higher.

Table 1. Soil organic carbon (SOC), total N, available P and K, bulk density and total microbes under organic and conventional farming system of rice at Jatiluwih.

Treatment	SOC	N-total	Available P	Available K	Soil Bulk density	Total microbes
	(%)	(%)	(ppm)	(ppm)	(Mg/m^3)	(CFU/ml)
Organic						
0-20 cm	3.338 a	0.252 a	15.840 a	133.63 b	0.510 c	1231200
20-40 cm	3.112 ab	0.222 b	11.050 b	124.47 b	0.666 b	
Conventional						
0-20 cm	2.496 bc	0.188 c	7.832 bc	161.87 a	0.777 a	71800
20-40 cm	2.038 c	0.180 c	7.414 c	153.12 a	0.712 ab	
5%LSD	0.638	0.014	3.334	12.576	0.102	

Notes: Values followed by the same letters in the same column are not significantly different at 5% LSD.

Soil bulk density

Under organic system for two years in Jatiluwih soil bulk density at 0-20 cm depth (0.510 g cm^{-3}) was significantly lower than that at 20-40 cm and at both depths under conventional counterpart (Table 1). The lower bulk density possibly due to lighter texture and higher SOC at the top of 0-20 cm depth (Table 1). In Wangaya Betan soil bulk density at 0-20 cm depth was significantly lower than that at 20-40 cm under both organic and conventional systems (0.562 and 0.492 g cm^{-3} respectively) (Table 2). In this area lighter texture at 0-20 cm was more associated to lower bulk density since the SOC under organic was not different from that under conventional system. Soil bulk density measured in the present study was different from that reported by Komatsuzaki and Syuaib (2010) reported soil bulk density at 0-10 cm depth (0.88 g cm^{-3}) of latosole after four years organic rice farming system in West Java, Indonesia was not significantly different from that under conventional counterpart. Different soil type could be contribute to the differences in soil bulk density.

Soil organic carbon (SOC), Total N, Available P and K

In Jatiluwih, soil organic carbon (SOC) under organic system 0-20 cm (3.338 %) was not different from that at 20-40 cm depth, but was significantly higher than that under conventional counterpart (Table 1). Incorporated rice straws by farmers after harvest and organic fertilizers applied may contribute to that higher SOC under organic system. Straw incorporation is an effective practice for improving the soil aggregate structure and stability.

Table 2. Soil organic carbon (SOC), total N, available P and K, bulk density and total microbes under organic and conventional farming system of rice at Wangaya Betan.

Treatment	SOC	N-total	Available P	Available K	Soil Bulk density	Total microbes
	(%)	(%)	(ppm)	(ppm)	(Mg/m^3)	(CFU/ml)
Organic						
0-20 cm	2.118 a	0.218 a	18.226 a	110.856 a	0.562 b	874400
20-40 cm	2.156 a	0.216 a	11.928 a	80.894 a	0.712 a	
Conventional						
0-20 cm	2.376 a	0.230 a	15.180 a	93.468 a	0.492 b	568000
20-40 cm	2.068 a	0.200 a	18.226 a	64.406 a	0.763 a	
5%LSD	-	-	-	-	0.118	

Notes: Values followed by the same letters in the same column are not significantly different at 5% LSD.

Meanwhile, in Wangaya Betan there were no significant differences in SOCs between the two systems as well as between those two soil depths (Table 2).

In Jatiluwih, organic system resulted in higher total N (0.252%) and available P (15.84 ppm) at 0-20 cm soil depth than those resulted from conventional system both at 0-20 cm and 20-40 cm depths (Table 1). On the other hand, available K at both two depths were significantly lower under organic (133.63 and 124.47 ppm respectively) than those under conventional system (Table 1). That was probably due to contribution of K nutrient derived from N-P-K-trace element fertilizer applied in the conventional system. Meanwhile, in Wangaya Betan, total N. available P and K were not significantly different under organic and conventional system (Table 2).

Total Soil Microbes

Total soil microbes were higher under organic sytem than that under conventional counterpart both in Jatiluwih (1231200 CFU/ml and 71800 CFU/ml respectively) (Table 1) and in Wangaya Betan (874400 CFU/ml and 568000 CFU/ml) (Table 2). Nakhro and Dkhar (2010) reported that organic carbon showed significant positive correlation with fungal and bacterial populations ($p \leq 0.05$). The application of organic fertilizers increased the organic carbon content of the soil and thereby increasing the microbial counts and microbial biomass carbon. The use of inorganic fertilizers resulted in low organic carbon content, microbial counts and microbial biomass carbon of the soil.

Soil Organic Carbon Sequestration

Soil organic carbon (SOC) storage has been widely considered as a measure for mitigating global climate change through C sequestration in soils (Huang *et al.*, 2010). In Jatiluwih, SOCS was the highest (81.354 Mg ha^{-1}) at 20-40 cm depth which was 57.58% higher than that at 0-20 cm depth in organic system and 52.43% and 26.60%% higher than those at the two depths under conventional systems respectively) (Figure 1). Although the SOC were not different, the bulk density was higher at deeper depth (20-40 cm) (Table 1) resulted in higher SOCS. It was obvious that in Jatiluwih the SOCS was significantly higher under organic than conventional system. Meanwhile in Wangaya Betan, there was no difference in SOCS between the two systems. The SOCS recorded both under organic at 20-40 cm depth was 60.252 Mg ha^{-1} which was not different from that under conventional system (63.366 Mg ha^{-1}) (Figure 2). Those SOCS were significantly higher than the SOCS at 0-20 cm depth both under organic and conventional systems. The SOCS also depends on cation exchange properties, soil texture and aggregation (Brochers and Perry, 1992). Pan *et al.* (2006) reported a close relationship between SOC sequestration rate and the sum of soil C converted from rice residues and organic amendments in paddy soil in a long-term experiment.

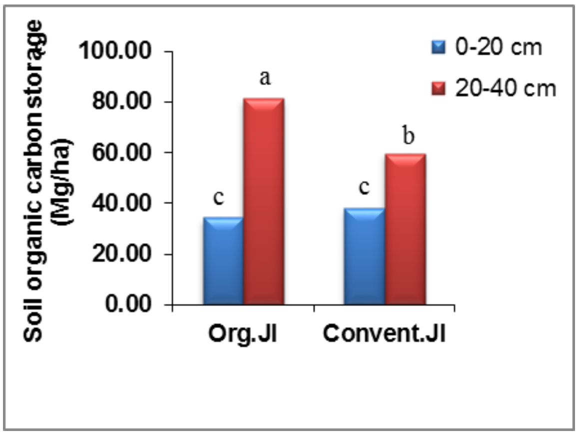

Fig. 1. Soil organic carbon storage at 0-20 cm and 20-40 cm depths under organic and conventional systems in Jatiluwih.

In general, a higher SOC content occurs with a lower soil bulk density. The SOC density is the total C at a certain depth. The total C is the product of the SOC content and the soil weight. The soil weight is the product of soil bulk density and soil volume. Paddy SOC density to a depth of 100 cm ranged from 89 to 97 Mg/ha in the Tai Lake region, compared with an average SOC density of 44 Mg/ha in the top 30 cm in China (Pan *et al.*, 2004).

Based on those data of those two fields, soil bulk density and soil depth, apart from the SOC, influenced C sequestration in the soil. The higher bulk density and the deeper of soil depth, resulted in the higher SOCS (soil carbon sequestration). Different soil texture in Jatiluwih and Wangaya Betan possibly associated with different SOCS (Brochers and Perry, 1992). The SOCS recorded in the present study was higher than that measured at the top 10 cm soil depth under organic (25 Mg ha^{-1}) and conventional (17.6 Mg ha^{-1}) rice farming in West Java reported by Komatsuzaki and Syuaib (2010). The higher SOC and deeper soil depth seemed to result in higher soil carbon sequestration in the present study.

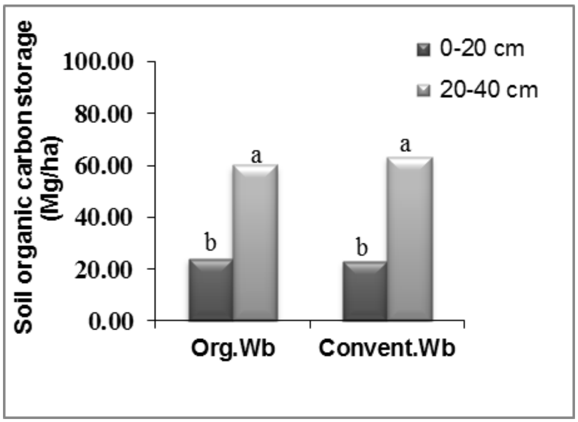

Fig. 2. Soil organic carbon storage at 0-20 cm and 20-40 cm depths under organic and conventional systems in Wangaya Betan.

Rice yields

Based on farmer's records in the area of both organic and conventional in the two locations, grain yields (at 12% grain moisture) of Red Local rice variety during two years was the average of 6.44 t ha^{-1} and 5.12 t ha^{-1}. These were in line with values reported by BPTP (2008). In West Java, the rice yields recorded in 2008 under organic and conventional farming systems were 3.2 and 4.1 Mg ha^{-1} respectively (Komatsuzaki and Syuaib, 2010). Different in rice variety as well as in management of organic farming system could cause the differences in rice yields of the present study and that of Komatsuzaki and Syuaib (2010).

Conclusion

After two years, organic system resulted in better soil quality and higher SOCS in Jatiluwih. Organic system significantly increased SOC (3.338%), total N (0.252%) and available P (15.84 ppm), particularly at 0-20 cm depth compared to conventional system. However K content was lower under organic system. Soil bulk density was significantly lower (0.510 Mg m^{-3}) but total soil microbes was higher under organic system. Soil carbon sequestration (SOCS) of 81.354 Mg ha^{-1} under organic system was significantly higher than conventional system. In Wangaya Betan, having different soil texture there were not significant differences in all variables measured, except soil bulk density, between organic and conventional system. The yields of Red local rice in Jatiluwih and in Wangaya Betan were average of 6.44t ha^{-1} and 4.48 t ha^{-1} under organic and conventional systems respectively.

References

Bhooshan N, Prasad C. 2011. Organic Farming: Hope of posterity. In: Hope of Posterity (Eds.), Organic Agriculture: UP Council of Agricultural Research (UPCAR), Lucknow, India. 1-10 p.

Blair GJ, Lefroy RDB, Lisle L. 1995. Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems. Australian Journal of Agricultural Research **46,** 1459-66.

BPS. 2010. Bali Dalam Angka 2010. Badan Pusat Statistik Provinsi Bali 2010. (In Bahasa Indonesia). 60-85 p. (In Bahasa Indonesia).

BPTP. 2008. Laporan Akhir Tahun Prima Tani Lahan sawah Intensif, Subak Guama, Marga, Tabanan. Balai Pengkajian Teknologi Pertanian Bali, Balai Besar Pengkajian dan Pengembangan Teknologi Pertanian, Badan Penelitian dan Pengembangan Pertanian Departemen Pertanian. p.50-65 (In Bahasa Indonesia).

Brochers JG, Perry DA. 1992. The influence of soil texture and aggregation on carbon and nitrogen dynamics in southwest Oregon forests and clear cuts. Canadian Journal of Forest Research **22,** 298-305.

Carpenter BL, Kennedy AC, Reganold JP. 2000. Organic and biodynamic management effects on soil biology. Soil Science Society of America Journal **64,** 1651-1659.

Chitra L, Janaki P. 1999. Combined effect of organic wastes and inorganic nutrients on the nutrient uptake and yield of rice in *kar* and *pishanam* seasons. Oryza **36,** 327-330.

Cui J, Zhang R, Bu N, Zhang H, Tang B, Li Z, Jiang L, Chen J, Fang C. 2012. Changes in soil carbon sequestration and soil respiration following afforestation on paddy fields in north subtropical China. Journal of Plant Ecology. Advance Access published September **5,** 2012. 1–13 p.

Gomez KA, Gomez AA. 1984. Statistical procedures for agricultural research. (2nd Edn), John Wiley & Sons, New York, USA.704 p.

Huang Y, Sun WJ, Zhang W, Yu YQ. 2010. Changes in soil organic carbon of terrestrial ecosystems in China: A mini review, Science China Life Sciences **53,** 766-775.

Komatsuzaki M, Ohta H. 2007. Soil management practices for sustainable agro-ecosystems. Sustainability Science **2,** 103-120.

Komatsuzaki M, Syuaib MF. 2010. Comparison of the farming system and carbon sequestration between conventional and organic rice production in West Java, Indonesia. Sustainability **2(3),** 833-843.

Lal R. 2007. Carbon sequestration. Philosophical Transaction of the Royal Society **363,** 815–830.

Minasny B, Sulaeman Y, MCBratney AB. 2011. Is soil carbon disappearing? The dynamics of soil organic carbon in Java. Global Change Biology **17,** 1917-1924.

Nakhro N, Dkhar MS. 2010. Impact of organic and inorganic fertilizers on microbial populations and biomass carbon in paddy field soil. Journal of Agronomy **9,** 102-110.

OECD. 2001. Executive summary. Environmental indicators for agriculture. Methods and results. Paris,

2001. 53 p.

Olson KR, Al-Kaisi MM, Lal R, Lowery B. 2014. Experimental consideration, treatments, and methods in determining soil organic carbon sequestration rates. Soil Science Society of American Journal **78,** 348–360.

Pan GX, Li LQ, Wu LS, Zhang XH. 2004. Storage and sequestration potential of topsoil organic carbon in China's paddy soils. Global ChangeBiology **10(1),** 79–92.

Pan GX, Xu XW, Smith P, Pan W, Lal R. 2010. An increase in topsoil SOC stock of China's croplands between 1985 and 2006 revealed by soil monitoring. Agriculture Ecosystems & Environment **136(1-2),** 133–138.

Pan GX, Zhou P, Zhang XH, Li LQ, Zheng JF, Qiu DS, Chu QH. 2006. Effect of different fertilization practices on crop carbon assimilation and soil carbon sequestration: a case of a paddy under a long-term fertilization trial from the Tai Lake region, China. Acta Ecologica Sinica **26(11),** 3704–3710. (in Chinese).

Pantawat S. 2012. Effect of organic fertilizer use in rice paddy to reduce greenhouse gases. 2nd International Conference on Environmental and Agriculture Engineering IPCBEE **37,** Singapore.

Pathak H, Kushwala JS, Jain MC. 1992. Evaluation of manurial value of biogas spent slurry composted with dry mango leaves, wheat straw and rock phosphate on wheat crop. Journal of Indian Society of Soil Science **40,** 753-757.

Rahman MM. 2013. Nutrient-use and carbon-sequestration efficiencies in soils from different organic wastes in rice and tomato cultivation. Communications in Soil Science and Plant Analysis **44(9),** 1457-1471.

Shofiyati R, Las I, Agus F. 2010. Indonesian soil database and predicted stock of soil carbon. In: Chen ZS, Agus F (eds). Proc. International workshop on evaluation and sustainable management of soil carbon sequestration in Asean countries. Indonesian Soil Research Institute (ISRI), Food&Fertilizer Technology Center for the Asian and Pacific Region (FFTC) and National Institute for Agro-environmental sciences (NIAES), 73-83 p.

Wang SX, Liang XG, Luo QX, Fan F, Chen YX, Li ZZ, Sun HX, Dai TF, Wan JN, Li XJ. 2012. Fertilization increases paddy soil organic carbon density. Journal of Zhejiang University Science B. **13(4),** 274–282.