Keynote Speech

Decomposition of Soil Organic Component under Organic Rice Cultivation in Bali, Indonesia

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Abstract
As mentioned in numerous sources of literature, soil organic carbon is the major component of the terrestrial carbon pool. Soil organic carbon in agricultural soil is a potential sink for the atmospheric carbon. The need for major changes in the global food system has been emphasized by numerous reports. Organic farming is considered to be one of the keys for the establishment of sustainable agriculture. In this study, our research team tried to compare the decomposition intensity of soil organic components under organic and conventional rice cultivations to find the effects of organic farming on the accumulation of soil organic carbon. From the examinations conducted in two organic and conventional paddy cultivation fields in Bali, we observed that the intensity of the decomposition of soil organic component was low in the organic paddy field, while high in the conventional. Not only the low input of fertilizers but also the input of plant residues can be considered to contribute for the stabilization of soil organic component in the organic farming systems.

Keywords: decomposition of soil organics, organic farming, paddy field, rice cultivation

Carbon Sequestration in Soil

Soil organic carbon is the major component of the terrestrial carbon pool. The awareness of greenhouse gas emissions and the concerns about the global warming issues has led to an increased interest in soil carbon sequestration (Banger *et al.*, 2009; Brar *et al.*, 2013; Follett, 2001). Soil organic carbon in agricultural soils is a potential sink for the atmospheric carbon. However, there are reports showing both negative and positive impacts of agricultural activities on carbon sequestration in soils (Brar*et al.* 2013). A 25-years examination of rice-wheat cropping system (Benbi and Brar, 2009) revealed a positive role of intensive agriculture in improving soil organic carbon status by 38%. On the contrary, Bhandari *et al.* (2002) and Regmi*et al.* (2002) reported negative effects of intensive agriculture on the organic carbon as well as the productivity of the soil.

Organic Farming and Carbon Accumulation

The need for major changes in the global food system has been emphasized during the past decades. Organic farming is a system aimed at producing food with minimal harm to the ecosystems, animals, or humans. Seufert *et al.* (2012) compared the yields of organic and conventional agriculture and found that the yields of organic farming systems are typically lower than those of conventional. However, those yield differences can be considered highly contextual because they are highly dependent on the system and the site characteristics. The declined yield with organic farming ranged from 5%, where the rain-fed legumes and perennials were grown in weak-acidic to weak-alkaline soils, to 34%, where the conventional and organic systems are most comparable, revealing complexities. Seufert*et al.* (2012) concluded that organic systems can nearly match conventional yields only under certain circumstances including good management practices, particular crop types, and favorable growing conditions.

Soil analysis on organic and conventional paddy fields in west Java, Indonesia, showed significantly higher soil organic carbon storage under organic farming (Komatsuzaki and Syuaib, 2010). Accordingly, it can be suggested that organic farming would help not only in mitigating global warming issues but also in establishing a sustainable food system. Furthermore, organic farming can be considered as one of the keys for the establishment of sustainable agriculture. Organic rice cultivation has also shown a high potential in improving the soil quality as well as in reducing the cost of chemicals that has recently being increasing with the increasing price of fossil fuels.

Rice Production in Indonesia

Rice production in Asia and other countries and regions has increased considerably by virtue of the Green Revolution, providing solutions to food shortages and poverty (Tilman *et al.*, 2002). In Indonesia, the rice yield per unit area showed an increment of approximately three-fold from 1760 kg ha^{-1} in 1961 to 5150 kg ha^{-1} in 2013. The country is currently the third largest producer of rice in the world. Concurrently, the domestic rice consumption has been increasing each year as a result of the dietary changes associated with population growth and economic development, making Indonesia a leading global rice consumer (USDA, 2015). As a result, the requirement for a stabilized and further improved rice production in the country is increasing during the recent years.

Cultivation of productive crops through the Green Revolution enhanced the use of large amounts of fossil energy resources for the agricultural machinery, chemical fertilizers, synthetic chemicals, etc. The increased use of chemicals led to various environmental problems such as reduced biodiversity, soil and water pollution, and eutrophication (Pimentel *et al.*, 1995).

Dissemination of Organic Farming in Bali

Organic farming has been attracting greater attention of Indonesia in the recent years because of the growing preferences of farmers and consumers for safety and health benefits of organic products and the governmental promotion for the use of organic products (Willer and Kilcher, 2011). This was triggered when the Asian financial crisis struck the country in 1998, leading to find the possible measures to return from a production system, which was becoming increasingly dependent on chemical fertilizers at the time, to a sustainable agricultural production system, which would be in balance with the environment (Syuaib, 2009). Farmers are interested in organic farming to obtain products with unit prices that are higher than those grown using chemical fertilizers, although it results in lower yields (Takada *et al.*, 2004). Some supermarkets in Indonesia have set up sections for organic rice, stimulating and encouraging the consumers to demand organic products.

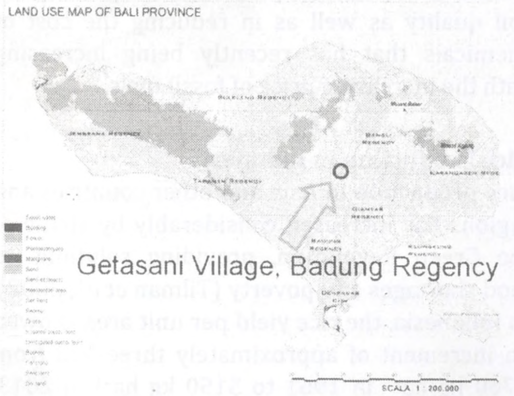

Figure 1: Study site

Based on the information provided by the Bali Agricultural Agency, Shiotsu *et al.* (2015) conducted a field research in the village of Getasani in the regency of Badung, where organic farming is practiced (Figure 1). Farmers in SubakBuangga were interviewed about their rice varieties, cultivation methods, cropping systems, and practicing of organic farming. Buangga comprises approximately of 200 farmers, managing a total paddy field area of 140 ha. Organic cultivation began in the Buangga in 2007 with an area of 10 ha. At the time of the survey (2014), an area of 40 ha was certified to be an organic farming system based on the national standards. Ciherang rice was grown in both the rainy and the dry seasons, whereas peanuts were grown as a secondary crop (Palawija). The farmers use only a form of cattle manure that is produced independently by a manure production group in Buangga consisting of 25 farmers who were supplying two cows each, totaling 50 cows.

The cattle manure production process consists of four steps. (1) Feed cattle with the weeds that have been collected from around the cattle sheds; (2) collect dung at the central square; (3) mix the dung with lime and ash, and ferment the mixture; and (4) spread out the manure mixture for drying. The annual production of cattle manure is 100–120 tons. In the distribution system, the manure produced by the farmers is purchased by the local government at a rate of Rp. 600 per kg, whereas the product is purchased by the farmers at a rate of Rp. 100 per kg. In other words, the farmers receive a governmental subsidy of Rp. 500 per kg for the cattle manure allocated to the system.

The paddy fields use 2000 kg ha^{-1} of cattle manure. The amount of cattle manure used for the paddy fields in Japan is 10,000 to 20,000 kg ha^{-1} (Japan Soil Association, 2015). Our interview with 10 farmers in Buangga revealed that the annual yield of organic rice is approximately 5.6 ton ha^{-1}, which is nearly equivalent to the mean yield in whole Bali.

According to Shiotsu *et al.* (2015), the Bali Agricultural Agency began to manage the certification of the organic agricultural products in 2009. Twenty-five farming groups were certified for the organic farming during the period of four years from 2009 to 2013. The crops certified as organic products included rice, onion, mangosteen, banana, dragon fruit, oranges, etc. Five farming groups were certified for organic rice farming, where the total cultivation area was 191 ha. One of these five groups was in Buangga (Shiotsu *et al.*, 2015).

Decomposition of Organic Component of Paddy Soils in Bali

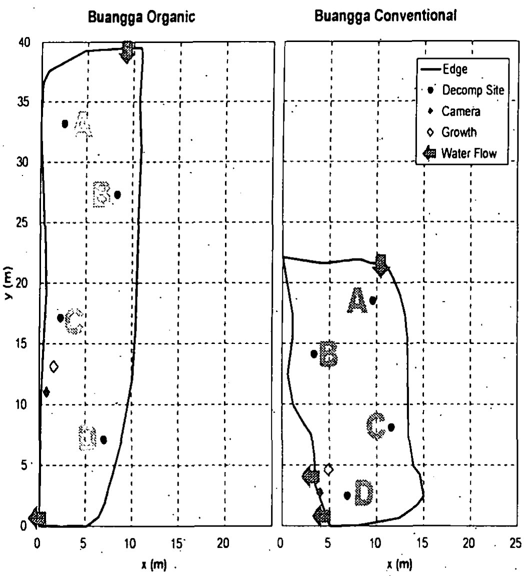

Figure 2: Organic and conventional paddy fields at SubakBuangga in the village of Getasani

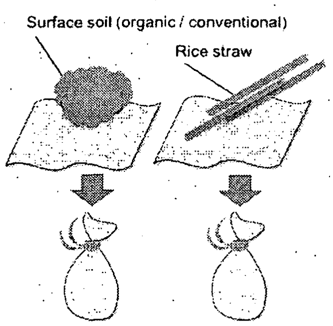

Figure 3: Surface soil and rice straw bound up by water-permeable and root-cutting sheet

In this study, our research team tried to compare the decomposition intensity of organic component under the organic and conventional cultivations of rice to determine how the organic farming affects the accumulation of organic carbon in soils. Our experiments were conducted at two paddy fields at SubakBuangga in the village of 1, 2).

Approximately 5-kg samples of surface soils (0-5 cm depth) were collected from both organic and conventional paddy fields (Figure 2). Soils passed through 2 mm sieve were air-dried for a period of two weeks at the room temperature. Rice straw from another paddy field was also air-dried for one week. Approximately 2.5 g of rice straw and 60 cm^3 of surface soil were wrapped up by root-cutting and water-permeable sheets (Figure 3, Toyobo STC, Osaka). As shown in Figure 4, 24 bags of surface soil and rice straw were installed in 2 fields (organic or conventional), 4 plots (A–D) in each field, and kept for 3 periods of time (40, 80, 120 days). To understand the circumstances when the cultivating system changed from conventional to organic, or organic to conventional, the organic surface soil bags were installed in the conventional paddy field, whereas the conventional soil bags were installed in the organic. In addition, the amount of root production was observed throughout the rice growth period by in-growth core method (Morita *et al.*, 2013).

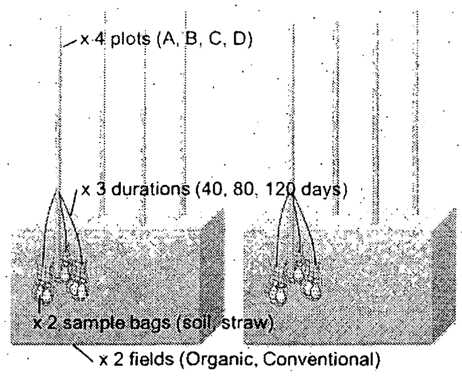

Figure 4: 24 bags of surface soil and rice straw were installed

Installed bags were collected from each plot at 40, 80, and 120 days after the transplanting of Ciherang seedlings (Figure 5). The oven-dried weight of rice straw was taken. Total carbon and total nitrogen contents of the soil samples were measured using CN analyzer(Sumigraph NC-22F, SCAS).

Figure 6 shows the decomposition of rice straw. The residue rate of rice straw at 40 days was slightly lower in the conventional paddy field. However, the rates at 120 days showed no significant difference between organic (52 ± 6 %) and for conventional (54 ± 6 %) fields.

The initial carbon contents of organic and conventional paddy fields were 1.91 ± 0.02 % and 2.62 ± 0.06 %, respectively. Figure 7 shows the total carbon and nitrogen contents, and the C/N ratio of surface soils after installation

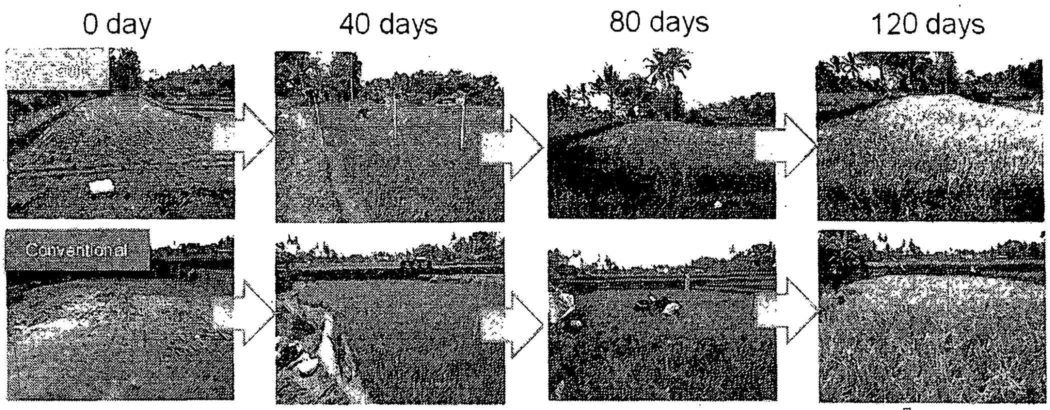

Figure 5: Paddy fields at 40 days, 80 days and 120 days after transplanting of Ciherang seedlings

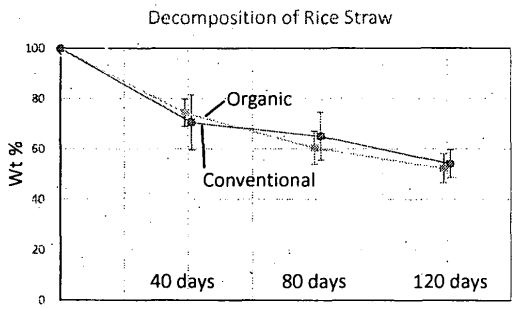

Figure 6: Residue ratio of Rice Straw

periods of 40, 80, 120 days under different farming systems. Under the organic cultivation, the carbon and nitrogen contents of the installed conventional soil showed a decrease at 40 days, and remained stable until the harvesting. The C/N ratio was also stable showing values between 10.1 and 10.2. On the contrary, under the conventional cultivation, the carbon and nitrogen in the installed organic soil did not show a rapid decomposition, but gradually decreased until the end of the experiment. The C/N ratio kept increasing from 9.2 to 9.4. These results suggest different intensities of decomposition for soil organic component, that is, low and stable in the organic, and high in the conventional paddy fields. The result of the in-growth core method showed that newly produced root length density from 80 to 120 days were 7.34 cm cm^{-3} and 10.13 cm cm^{-3} forthe organically and conventionally cultivated rice, respectively (Shiotsu *et al.*, unpublished). The high production of rice root in the conventional paddy fields supports our finding of higher decomposition intensity of soil organic component in the conventional fields.

The essential driver of the decomposition of soil organic component is soil microorganisms such as bacteria and fungi. By an examination in vegetable fields, Nagaoka *et al.* (2011) reported that fungal flora can easily be changed by implementing an organic farming system;

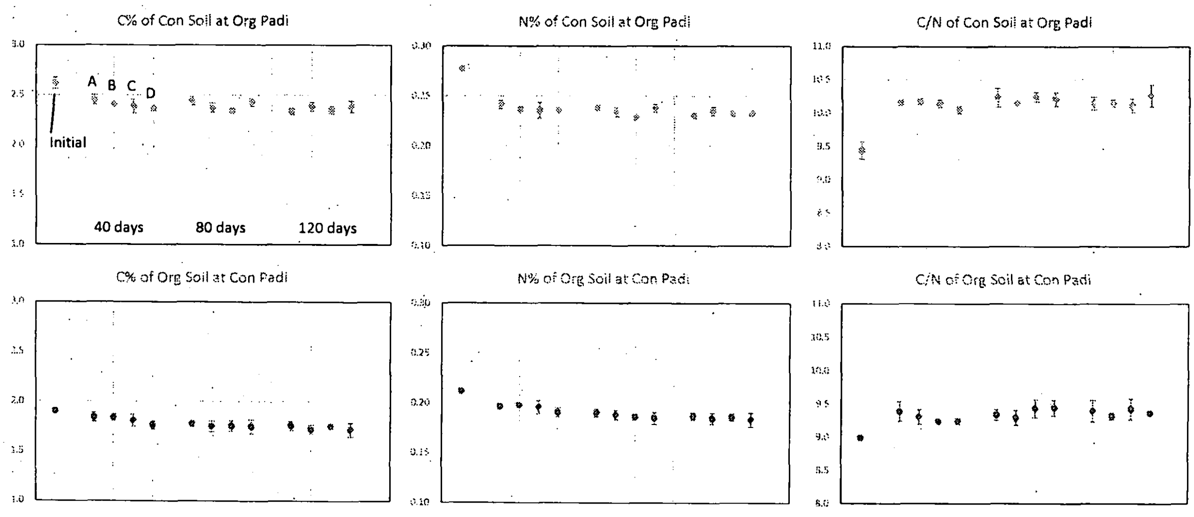

Figure 7: The total carbon content, the total nitrogen content, and the C/N ratio of surface soil after installation for 40, 80, and 120 days under different farming systems

however, bacterial flora tends to be stable for several years. Implementation of organic farming might drastically change the input of plant resides, including root, affecting soil microorganism, mainly the fungi. Not only the low input of fertilizers but also the input of plant residues can be considered to contribute for the stabilization of soil organic component in the organic farming systems.

References

Banger K, Kukal SS, Toor G, Sudhir K, Hanumanthraju TH 2009. Impact of long-term additions of chemical fertilizers and farm yard manure on carbon and nitrogen sequestration under rice-cowpea cropping system in semi-arid tropics. Plant and Soil 318, 27–35.

Benbi DK and Brar K 2009. A 25-year record of carbon sequestration and soil properties in intensive agriculture. Agronomy for Sustainable Development 29, 257–265.

Bhandari AL, Ladha JK, Pathak H, Padre AT, Dawe D, Gupta RK 2002. Yield and soil nutrient changes in a long-term rice-wheat rotation in India. Soil Science Society of America Journal 66, 162–170.

Brar BS, Singh K, Dheri GS, Balwinder-Kumar 2013. Carbon sequestration and soil carbon pools in a rice-wheat cropping system: effect of long-term use of inorganic fertilizers and organic manure. Soil & Tillage Research 128, 30–36.

Follett RF 2001. Soil management concepts and carbon sequestration in cropland soils. Soil and Tillage Research 61, 77–92.

Japan Soil Association 2015. Available online: http://www.japan-soil.net/

Komatsuzaki M and Syuaib MF 2010. Comparison of the farming system and carbon sequestration between conventional and organic rice production in west Java, Indonesia. Sustainability 2, 838–843.

Morita S, Sekiya N and Abe J 2013. Grasping root system development. Root Research. 22: 111–118. (In Japanese and English abstract)

Nagaoka K, Karasawa T, Urashima Y, Yamazaki S, Takenaka M, Sato F, Kato N 2011. Microbial community shift at initial stage of organic farming implementation. Abstracts for annual meeting of Japanese Society for Soil Science and Plant Nutrition 57, 40.

Pimentel D, Harvey C, Resosudarmo P, Sinclair K, Kurz D, McNair M, Crist S, Shprita L, Fitton L, Saffouri R, et al 1995. Environmental and economic costs of soil erosion and conservation benefits. Science-AAAS-Weekly Paper Edition 267, 1117–1122.

Regmi AP, Ladha JK, Pathak H, Pasquin E, Bueno C, Dawe D, Hobbs PR, Joshy D, Maskey SL, Pandey SP 2002. Yield and soil fertility trends in 20-year rice-rice-wheat experiments in Nepal. Soil Science Society of America Journal 66, 857–867.

Seufert V, Ramankutty N, Foley JA 2012. Comparing the yields of organic and conventional agriculture. Nature 485, 229–232.

Shiotsu F, Sakagami N, Asagi N, Suprapta DN, Agustiani N, Nitta Y, Komatsuzaki M 2015. Initiation and dissemination of organic rice cultivation in Bali, Indonesia. Sustainability 7, 5171–5181.

Syuaib MF 2009. Perspective of sustainable agriculture in Indonesia: Keep growing in harmony with environment. Proceedings of Postgraduate GP Education Workshop on From Environmental to Sustainable Science: Thinking the Shift and the Role of Asian Agricultural Science, Ibaraki, Japan, pp 93–99.

Takada N, Iwamoto N, Ohga K 2004. Organic farming movement in central Java. Japanese Journal of Tropical Agriculture 48, 270–273.

Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S 2002. Agricultural sustainability and intensive production practices. Nature418, 671–677.

United States Department of Agriculture, USDA 2015. Indonesia: Grain and Feed Update. Available online: http://www.fas.usda.gov/data/indonesia-grain-and-feed-update

Willer H and Kilcher L Eds 2011. The World of Organic Agriculture. Statistics and Emerging Trends 2011; International Federation of Organic Agriculture Movements (IFOAM): Bonn, Germany and Research Institute of Organic Agriculture (FiBL). Frick, Switzerland.