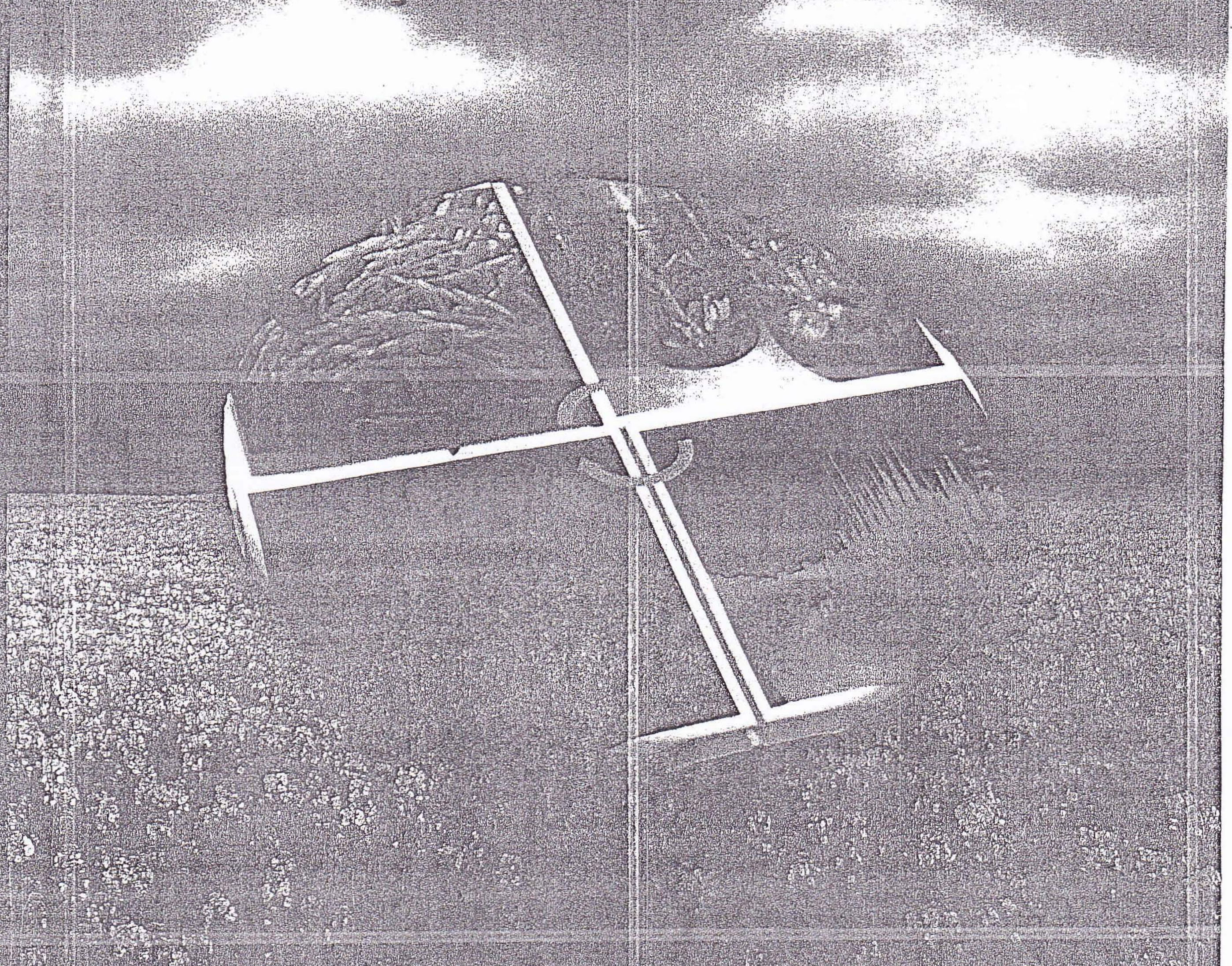
Sustainable Agriculture and New Biotechnologies

Edited by Noureddine Benkeblia



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CHAPTER 14

New Farm Management Strategy to Enhance Sustainable Rice Production in Japan and Indonesia

Masakazu Komatsuzaki and Faiz M. Syuaib

CONTENTS

14.1 INTRODUCTION

Rice is a common and essential food plant in Asia, and from the 1960s to recent years, rice yields have increased remarkably. Since the 'green revolution' programme launched in the late 1960s, application of chemical fertilizers has dramatically increased because of governmental encouragement to succeed in the food self-sufficiency goal. Chemical fertilizer consumption in the agriculture sector reached five times the level of 1975 in 1990 and increased slightly afterwards in Japan and Indonesia. In Indonesia, since the economic crisis, in 1998 the government reduced the subsidy on fertilizers and therefore the cost of agriculture input has increased; thus farmers have reduced the use of chemical fertilizer and started improving their application methods, and organic fertilizer has presently become more favourable. A similar situation occurred even in Japan: with an increase in chemical fertilizer price due to increasing oil prices, most farmers have evinced interest in using organic fertilizer. '*Bochashi*' is the traditional way of making compost using agricultural subproducts and waste in Japan, and this technique has spread widely to other Asian countries, including Indonesia.

Recent intensive research is aimed at evaluating differences in the conservation rice farming system between Indonesia and Japan and also at finding out the common aspects. To develop the ecological management of the farming system, an ecosystem approach is needed. The ecosystems between Indonesia and Japan are so different, even though we are all facing similar situations such as global warming and globalization. Through these case studies, we will discuss what is needed to achieve a sustainable ecosystem, and how we can collaborate to develop a community-based approach. These framework studies will be able to point out the appropriate technical transfer and development for each agro-ecosystem. This chapter addresses the similarity and variability of organic rice production from the viewpoints of regional and global sustainability between Japan and Indonesia.

14.2 RICE PRODUCTION AND THEIR SUSTAINABILITY IN JAPAN

14.2.1 Country Facts and Agricultural Practices at a Glance

Japan is an island country, made up of more than 3000 islands of a large strato-volcanic archipelago along the Pacific coast of Asia. Japanese agriculture is more than 2000 years old. Today, agriculture represents only 1% of Japan's gross domestic product (GDP). Approximately 73% of the land area of Japan is mountainous and about 13% is farmland (4,628,000 ha). Rice (*Oryza sativa* var, *japonica*) has been recognized as the most important crop from economic, political and cultural perspectives in Japanese agricultural history. Rice plants grow well in Japan, with its abundant rainfall and high summer temperatures. Therefore, paddy rice occupies more than half of the total cultivated land (2,516,000 ha).

Up until the 1940s, Japanese agriculture had many features of sustainability. Most food was grown in integrated, mixed farming systems with a closed-loop nutrient cycle. Traditionally, Japanese farming used to be an environmentally friendly system because most crop rotations included both summer cash crops and winter grain crops, such as wheat and barley. However, recent statistical data have revealed that the annual ratio of crop planting area in cultivated fields was 94.4% in 2004, representing a dramatic decrease over the past few decades (Statistics of Agriculture, Forestry and Fisheries, 2005). This suggests that Japanese crop rotation systems are being destroyed and intensive farming and single-cropping systems are now widely being employed. These new farming systems can degrade the quality and health of soil through the increase of synthetic chemical inputs and leaching of soil residual nutrients into groundwater (Kusaba, 2001).

Today, agricultural technologies that are overly dependent on chemical inputs might be increasing productivity to economically meet food demand, but they may also be threatening agricultural ecosystems and local environments. With the growing interest in reducing excessive synthetic chemical inputs to farming, the importance of cover crops as determinants of soil quality has been

14.2.2 Rice Production and Sustainable Farming System Using Cover Crops

More than 2000 years ago, farmers in China and the Mediterranean countries sowed cover crops to improve soil productivity. Chinese milk vetch (*Astragalus sinicus* L.), which was the most useful cover crop in China more than 1000 years ago, was introduced in Japan from China in about the seventh century. In 'Nougyou Zensyo', one of the corpuses of agricultural techniques of the Edo period that was published in 1697, green manure and cover crops were noted as the most important tools for improving soil fertility. Chinese milk vetch used to be planted in most Japanese paddy fields as a cover crop until the 1960s, when it was replaced by increasing use of chemical fertilizers on farmland (Yasue, 1993). Some beneficial impacts on the agro-ecosystem using cover crops in paddy fields are given below.

14.2.2.1 Soil Residual N Scavenging

Wet paddy rice cultivation is one of the traditional agricultural techniques in Asia. In Japan, half of all croplands are cultivated with paddy rice; and the total value of rice in Japan exceeds its monetary return because of its significantly high quality in the world marketplace. If a grower were to base the decision to grow rice solely on the market value of rough rice, it is doubtful that rice would be grown at all. However, when the overall value of rice and its effects on the environment, such as flooding water in the fields, storing water after intense rainfalls and the overall profitability of the land, are considered, the benefits of rice production outweigh the costs. Moreover, paddy fields have unique ways of regulating the movement, accumulation and transformation of SOM and nitrogen because paddy fields are controlled by long-term seasonal oxidation–reduction interaction. Therefore, in Japan, paddy fields play a significant role in the country's agricultural ecosystems.

In general, soil subsidence is the loss of surface elevation due to decomposition (mineralization) of organic soil. Microbial activity is the major cause of mineralization and requires the presence of oxygen. A deep water table allows a large amount of soil to be aerated, which promotes mineralization (Snyder et al., 1978). High summer temperatures accelerate the process (Bonner and Galston, 1952). Paddy rice effectively stops the subsidence of muck soil during the hot summer months, the time of year when the rate of subsidence is the highest (Snyder et al., 1978).

Wet paddy farming also has benefits for improving water quality. Nitrogen reaction in paddy fields can effectively process inorganic N through nitrification and denitrification, ammonia volatilization and plant uptake. In Japan, 55% of all land used for agriculture is paddy fields. However, paddy rice production requires abundant amounts of water, accounting for 95% of total agricultural water use (Tabuchi and Hasegawa, 1995), as well as a lot of chemical fertilizer. Therefore, paddy fields play a particularly significant role in catchment environments. Depending on the amounts of water and fertilizer that are used and how they are applied, some paddy fields remove nutrients (Takeda et al., 1997). The recycling of irrigation water may reduce the need for both irrigation water and nutrient inputs in agricultural catchments (Kudo et al., 1995).

However, these benefits occur only during the growing season, when paddies are flooded. After the rice is harvested in autumn, most paddy fields are not irrigated and are left fallow from autumn to spring. This dries out the soil, which can lead to N leaching. For example, in the area around Biwako, the largest lake in Japan, considerable N leaching from paddy fields to the lake has been observed in winter (Tanaka, 2001). However, when planted with winter cover crops, paddies have shown significant environmental benefits. Figure 14.1 illustrates the cover crop benefits in paddy fields during winter. As we can see, non-legume cover crops have particularly significant N uptake during winter in paddy fields and add organic matter to the soil (Komatsuzaki, 2009).

Paddy field rice can conserve N in the soil under flooded conditions; however, residual soil N represents a potential environmental concern when fields are no longer flooded. Komatsuzaki (2009) reported that winter annual non-legume cover crops provide an alternative means of conserving

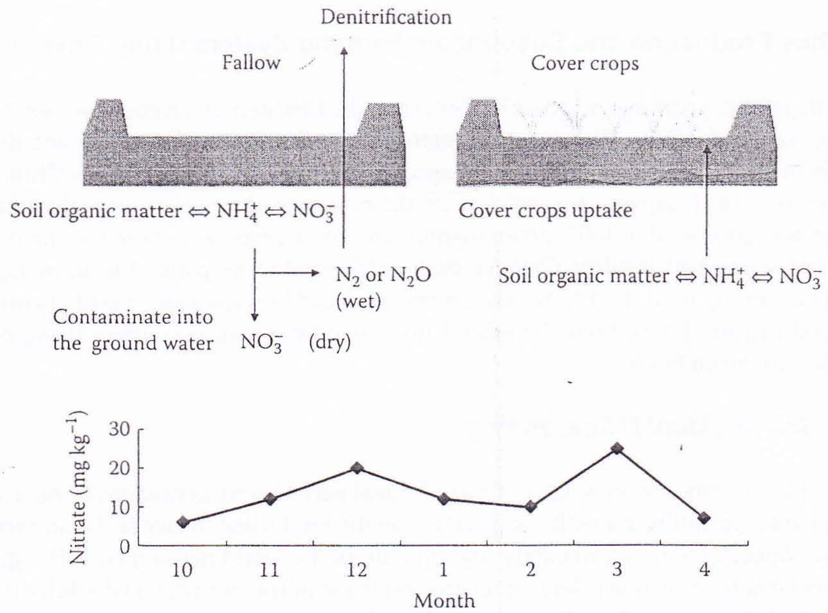


Figure 14.1 Illustration of N dynamics between fallow and cover crop fields in the non-irrigated winter season and soil nitrate concentration change during the entire non-irrigated season in the Kanto region of Japan.

residual soil N following rice harvest. A two-year field experiment was conducted at the Ibaraki University Experimental Farm to compare dry matter (DM) and N accumulation of rye (*Secale cereale* L.), oat (*Avena sativa* L.), triticale (*Triticum secale* L.), wheat (*Triticum aestivum* L.) and fallow (no cover) in relation to soil residual N levels. Figure 14.2 shows that DM and N accumulation by the following April were of the order rye > triticale > wheat = oat > fallow, whereas residual soil N levels occurred in the reverse order.

Residual soil N levels exerted the greatest influence on cover crop DM accumulation, with differences in N levels becoming more pronounced by the April sampling date. By 17 April, DM differences between the low and high residual soil N levels were 3.45 versus 6.82 Mg/ha for rye (98% increase), 1.15 versus 1.45 Mg/ha for oat (26% increase), 1.49 versus 1.99 Mg/ha for wheat (34% increase) and 1.70 versus 2.98 Mg/ha for triticale (75% increase). N accumulation for rye was greater than for oat and wheat across all planting dates, whereas triticale showed moderate ability to accumulate N (Komatsuzaki, 2009).

These results demonstrated that non-legume cover crops have great potential for conserving soil residual N. However, additional research would be needed to determine the contribution of cover

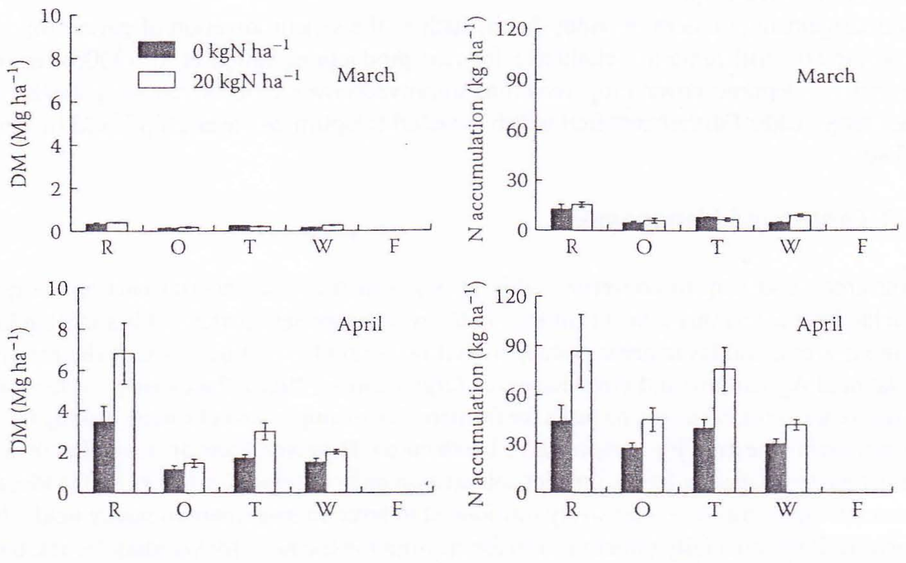


Figure 14.2 Cover crop DM accumulation and N accumulation in relation to cover crop type, soil nitrogen level and growth termination. Cover crops are indicated by letters as follows: R for rye, O for oat, T for triticale, W for wheat and F for fallow. Vertical bars indicate standard error. (Data from Komatsuzaki, M. 2009. *Jpn J Farm Work Res* 44(4):201–210.)

and Sutter counties in California, USA, cover cropping with vetch reduced the rice fertilizer N requirement by 30–100 lb N/acre, with an average over several experiments of about 50 lb N/acre (Pettygrove and Williams, 1997). Similar values have also been reported for Japanese paddy fields. For example, Asagi and Ueno (2009) reported that winter white clover, hairy vetch and crimson clover with no-fertilizer plots showed similar yields as fertilized plots, suggesting that the cover crop contributed about 80 kg N/ha to rice growth.

With the increasing costs of chemical fertilizer and energy, a new no-tillage rice planting system that uses hairy vetch as a cover crop has been developed in Japan. In field experiments, hairy vetch planted in the fall covered the land well in the spring, and suppressed weed growth. Two days before rice transplanting, fields were flooded, and a no-tillage transplanter was used for transplanting rice without tillage and pudding. In this system, hairy vetch contributed about 60 kg N/ha to rice growth (National Agricultural Research Center for the Kyushu Okinawa Region, 2003).

Legume cover crops can supply enough nutrients for rice growth because they require relatively low N input in the flooded condition. However, Asagi and Ueno (2006) reported that white clover could produce a high level of biomass and can fix a sufficient amount of nitrogen for rice plants but only a small amount of the fixed nitrogen was taken up by rice plants in the past, because of the discrepancies in N patterns between the legume supplier and N uptake by the crop.

By estimating cover crop N content shortly before incorporation, a rice grower can adjust the rate of N fertilizer in response to year-to-year variations in cover crop growth. Synchronization of cover crop N release with demand from the following rice crop is needed for efficient production. Release of N from cover crops depends on species, growth stage, farming method and climate. Irrigation is a practical method that can control the timing of the killing and decomposition of the legume and following N mineralization (Ueno, 2004).

Asagi and Ueno (2009) evaluated the effects of irrigation timing on N concentration in the soil, rice plant growth and yield, and found that delayed irrigation could retard legume decomposition and N mineralization. The rice harvested from cover crop plots that were irrigated at 30 days after transplanting had a 13.7% higher grain weight than rice from plots that had been irrigated 10 days before transplanting. It appears that the delay of N mineralization was more effective for supplying available N to the rice crop.

Soil management practices in paddy fields, such as the synchronization of cover crop N release with crop growth, still remain a challenge for rice production. Sainju et al. (2006) reported that legume and non-legume cover crop biculture improved cover crop N release patterns and also improved crop yields. Further research will be needed to optimize cover crops used in biculture in paddy fields.

14.2.2.3 Landscape Management

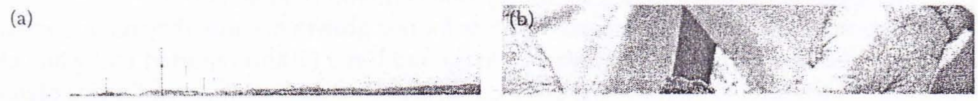
Cover crops also help to conserve paddy levees, which are an integral part of the traditional Japanese landscape, and this aspect is unique in the world. Japanese paddy fields are often located in mountainous areas, and levee areas occupy a total of 143,600 ha, about 5.7% of the area of paddy fields (National Agriculture and Food Research Organization, 2008). Paddy ridge or levee management is one of the most burdensome tasks for farmers. For example, most farmers usually mow levees 6 to 8 times during the growing season with a brush cutter. However, there are a number of ecological benefits: for instance, paddy levees prevent soil erosion and conserve rice traces and landscapes.

Perennial cover crops are intensively introduced to levee management in paddy fields. *Imperata cylindrical* L. is an especially effective crop for eliminating the need for weeding levees, because of its wide leaves, creeping, short plant height, early growth and early root development (Tominaga, 2007). When these ecological functions dominate levee slopes, they can suppress weeds and reduce the need to mow. For example, the National Agriculture and Food Research Organization (2008) reported that if *I. cylindrical* L. were planted at 12 hills/m, it would dominate the levee slope two years later and would reduce the amount of labour required for mowing by about 50%.

Zoysia japonica and *Ophiopogon japonicus* Gyokuryu are also effective cover crops for levee areas. They are low plants that have significant ability for ground covering, are tolerant to trampling and provide traction against slipping during levee work. Since these cover crops were originally wild plants that were domesticated in Japan, such management strategies should also help conserve local agro-ecosystems and biodiversity.

14.2.3 Sustainable Rice Production Practices in Japan

Flooding paddy rice—winter non-legume cover crops are an appropriate farming system to develop sustainable farming, because they can prevent the leaching of soil residual nutrient, add



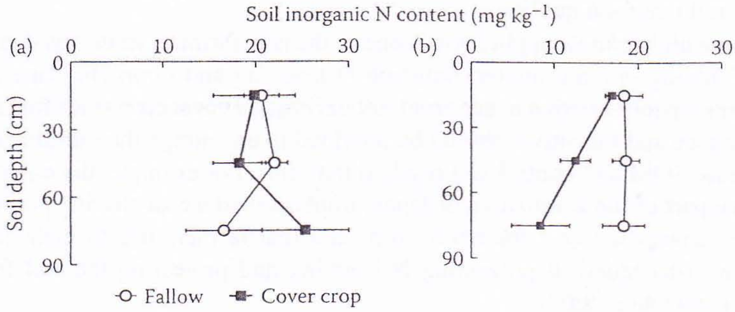


Figure 14.3 Soil inorganic N distribution between cover crop and winter fallow in a paddy rice field. Soil inorganic N was measured on 13 October 2000 when cover crop was seeded (a) and on 17 April 2001 when cover crop was terminated (b). (Data from Komatsuzaki, M. et al. 2004. *Jpn J Farm Work Res* 39:23–26.)

SOM, improve yields and eliminate fertilizer for rice growth (Plate 14.1). Italian ryegrass (*Lolium multiflorum* Lam.) was used as a non-legume cover crop in paddy fields. Komatsuzaki et al. (2004) reported that winter annual non-legume cover crops provide an alternative means of conserving residual soil N following rice harvest in Kanto, Japan.

Non-legume cover crop was grown well when sown immediately after rice harvest. The cover crop biomass was 4.4 Mg/ha and N accumulation was 90 kg N/ha. Figure 14.3 shows the soil inorganic N distribution between winter cover crop and fallow treatment in a paddy field. There were no significant differences in soil inorganic N content between cover crop and fallow treatment; however, cover crop soil showed significantly lower inorganic N content compared with fallow soil in 0–90 cm soil depth layer. Non-legume cover crop was to provide enough soil cover during the winter, and supply enough biomass and N for subsequent rice production (Komatsuzaki et al., 2004).

Because cover crop residue decomposition is difficult to manage, cover crop N release often decreases rice food quality due to increase in grain protein content. In this regard, *bochashi* is one of the alternatives for enhancing cover crop residue decomposition after incorporating with cover crop residues before puddling. Farmers use a self-produced organic fertilizer called '*bochashi*', which is composed of 60% rice bran, 20% rice chaff and 20% soybean mill (in volume). Nutrient values of this organic fertilizer are 3.7% for nitrogen, 2.3% for phosphorus and 1.6% for potassium (in dry base). *Bochashi* also has benefit in reducing the cost for nutrient in rice production, and can cut 56% of the fertilizer cost compared with chemical fertilizer.

The combination of non-legume cover crop and *bochashi* application showed good performance in paddy rice production. Table 14.1 shows rice yield response between winter cover crop and fallow treatment in a paddy field. In both treatments, *bochashi* was applied as an initial fertilizer. The results suggest that cover crop with *bochashi* treatment enhanced rice yield and rice food quality: especially, cover crop with *bochashi* treatment increased the straw–grain ratio and reduced protein

Table 14.1 Rice Yield Response between Winter Cover Crop and Fallow Treatment

Treatment	No. of Hills (hill/m^2)	Straw (g/m^2)	Grain (g/m^2)	Straw–Grain Ratio %	Food Quality	Amylose %	Protein %
Cover crop	397.0	488.6	552.6	58.3	82.0	18.4	6.0
Fallow	337.3	483.2	451.3	52.4	81.7	18.5	6.1
Significance	NS	NS	NS	*	*	NS	*

Source: Data from Komatsuzaki, M. 2008. *Bokuso to Engei* 56(6):10–14.
* Indicates significance at 5%, and NS indicates non significance.

content in the grain. Winter cover crop and *bochashi* have great potential in reducing N leaching in the river and pond from paddy fields, reducing the cost of fertilizer for rice production, and improving rice yield and rice food quality.

Cover crop with *bochashi* application is one of the new farming strategies that improves the soil as a result of adding organic matter, reducing N leaching and improving rice yield and quality; however, cover crop introduction needs an additional cost for cover crop seeds for farmers. Therefore, political assistance and incentives should be provided to encourage the introduction of cover crops that can increase SOM and control soil residual nutrients. For example, the city of Ushiku, located in the northern part of the Kanto area of Japan, implemented a cost-sharing programme in 2004 in which the city shares the cost for cover crop seed that farmers use in their crop rotation. This programme has succeeded in preventing N leaching and protecting the soil from wind erosion (Komatsuzaki and Ohta, 2007).

14.3 RICE PRODUCTIONS AND THEIR SUSTAINABILITY IN INDONESIA

14.3.1 Country Facts and Agricultural Practices at a Glance

Indonesia is the world's largest archipelagic country, which extends between two continents, Asia and Australia, and between two oceans, Pacific and Indian. The Archipelago stretches over 5500 km from east to west and 1900 km from north to south, consisting of more than 17,000 islands, an 81,000 km coastline, 1.9 million km^2 land territory and 3.2 million km^2 of sea territory. Indonesia is made up of reservoirs of rich biodiversity in tropical agro and marine ecosystems, which contain various indigenous varieties of flora and fauna, many of them are typically indigenous and are never found in other parts of the world.

Indonesia lies on the zone of tropical environment with almost no extreme changes in weather. The daily temperature range is 23–33°C in the low plains and 15–27°C in the highland areas. The east and west monsoon strongly influence the weather, which periodically brings the dry season in April–September and the wet season in October–March. The annual average rainfall in the country is about 2400 mm, but varies widely among areas, from about 1000 to 4500 mm. However, the farming system in the country is generally determined as the variable of rainfall pattern rather than temperature. Based on soil, rainfall and length of the growing period, five pragmatic agro-ecological zones might be recognized in the country: (1) dryland–dry climate, (2) dryland–wet climate, (3) highland, (4) lowland irrigation and (5) tidal swamp.

More than 90% of the land surface of Indonesia is still covered by vegetation, as tropical rainforest, woodland, mangrove, agricultural crops and grassland. Based on the land utilization features of Indonesia, more than 30% (58 million ha) is recognized as agricultural land (lowland, upland, estate plantation, grassland, pond and dike), 60% as forest (permanent and industrial forest) and 3% as housing and settlement area (Central Bureau of Statistics (CBS), 2006). A rough estimation of land

Table 14.2 A Rough Estimation of Land Utilization in Indonesia

No.	Type of Land Utilization	Area (× 1000 ha)	% of Total Land Area
1	Permanent forest	114,192	60.0
2	Woodland/agro-forestry	9304	4.9
3	Estate plantation	18,490	9.7
4	Dryland (upland and garden)	15,585	8.2
5	Temporary fallow land	11,342	6.0
6	Wetland (rice field)	7886	4.1
7	Housing/settlement	5686	3.0
8	Swamp/marsh land	4755	2.5
9	Grassland/meadows	2432	1.3
10	Pond and dike	779	0.4
	TOTAL LAND AREA	190,457	100.0

Source: Summarized from BPS and the Ministry of Agriculture (2006).

fields, (2) upland (rainfed–dryland) secondary crop fields, (3) estate plantations (industrial crops) and (4) agro-forestry. Lowland and upland crops are predominantly practised by common or individual farmers, whereas estate plantation and agro-forestry are industrial or company-based management.

Humans and animals remain predominant power sources of farm work in Indonesia. Mechanization is a 'luxury' for most Indonesian farmers. In some 'well-developed' areas, farm mechanization has been applied; however, it still has a narrow meaning and is limited to the utilization of a hand tractor for land preparation or the utilization of a power thresher and a rice milling unit for postharvest handling. Utilization of a four-wheel tractor, power sprayer, cultivator and other machinery is merely found in bigger commercial estate plantations, such as oil palm, sugarcane or some industrial crop plantations. These facts clearly show that mechanization is only applied for <20% of total farm activities in Indonesia (Syuaib, 2006).

Food self-sufficiency has therefore always been the main goal of the agricultural development agenda of the Indonesian government. The increasing demand for food has resulted in intensive agricultural practice. Since the so-called 'green revolution' era, intensive exploitation of land and increasing application of chemical fertilizers have been practised by most farmers so as to increase the yield. Straight fertilizers (N, P, K) in accordance with the recommended composition have been used for decades for most farming systems in Indonesia, for crop farming and industrial plantations as well. In 1990, the total national consumption of fertilizers reached five times that in 1975, and increased slightly afterwards.

Since the economic crisis, in 1998 the government reduced the subsidy on fertilizers and therefore the cost of agriculture input has increased; thus, farmers reduced the use of chemical fertilizers and started improving their application methods, and organic fertilizer became more preferable. Although the economic crisis in the industrial sector has not fully recovered yet, agricultural estates have been intensified to lift up the national income; fertilizer consumption for estate plantations has therefore been increasing since 2002. Figure 14.4 shows the total domestic consumption of agricultural fertilizers and the total consumption for crop farming and estate plantation. Figure 14.5 shows the domestic retail price of four common fertilizers consumed in Indonesia. The figures show that the retail price of fertilizers doubled since the economic crisis of 1998 (Figure 14.5) when the prices of fuel and other industrial input materials were increasing. At the time the consumption of fertilizer was then decreasing for some years, and afterward it has been increasing again since 2002 (Figure 14.4). The increase of chemical fertilizers from 2002 is mainly caused by the increasing consumption of estate plantation due to planted area expansion. Meanwhile, the demand of fertilizer for food crop farming actually decreased due to the significant increase of retail price which was not affordable for common farmer.

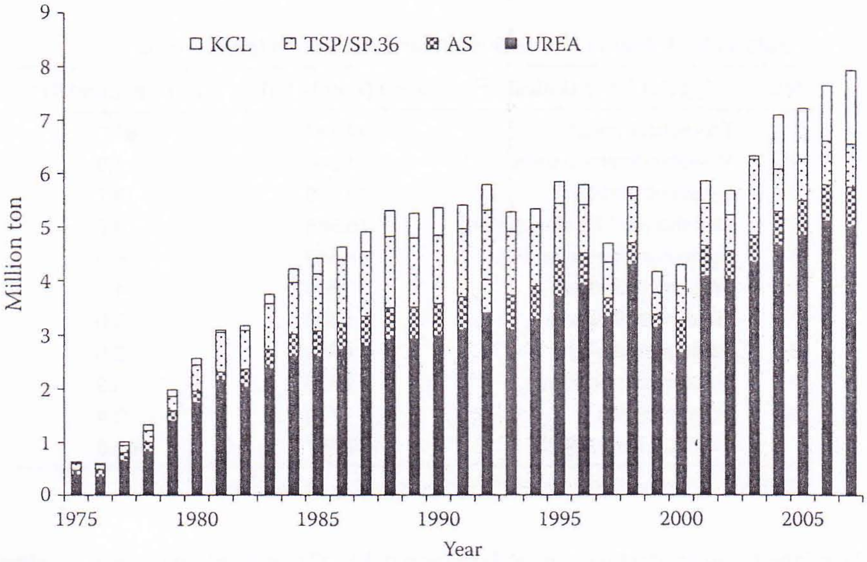
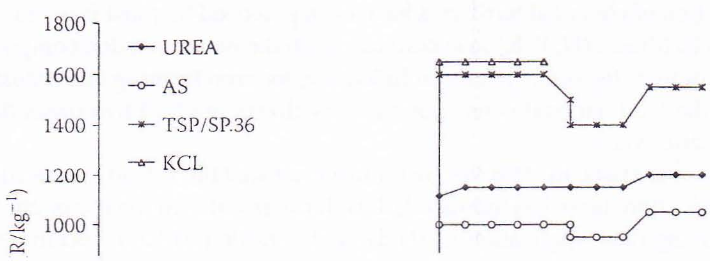


Figure 14.4 Domestic consumption of fertilizers in Indonesia.

Agriculture is the dominant land use, the largest consumer of water and one of the main contributors to groundwater and surface water pollution as well as a powerful emitter of greenhouse gases. Furthermore, increasing inputs of chemicals and fertilizers may pose a threat to the natural areas surrounding farmlands. Concerning the present condition of agricultural practices in Indonesia (as well as in many countries in Asia), we need to adjust our understanding and formulate an action strategy to develop better and sustainable agricultural practices in the future. A sustainable approach to agriculture is necessary in order to keep increasing the productivity to fulfil human needs, whereas at the same time it has to be in harmony with the environment so as to conserve resources and maintain environmental balance.



14.3.2 Rice Production and Farming System in Indonesia

Concerning the amount of production, Indonesia is now the world's number 3 among rice producers, after China and India. However, the amount of domestic consumption is about the same as production itself, since more than 95% of the population consumed rice as the staple food, and therefore paddy is the most important crop grown in Indonesia. Paddy is grown on flat lowland up to terraced middle-range altitude. Java Island is the main area for growing paddy, which comprises about 50% of total harvested area and 60% of total rice production of the country. The other major areas of paddy fields are Bali, Lombok, west and southern parts of Sumatra and South Sulawesi (Syuaib, 2009).

Owing to the advantage of tropical climate conditions, a common feature of Indonesian farming activities is the fact that crops can be grown any time of the year. By using short growth period varieties, it is theoretically possible to grow three crops a year in Indonesia. However, the average cropping indexes of the country so far are still 1.8 and 1.0, respectively, for irrigated and non-irrigated fields.

Rice farming in Indonesia is dominated by small farms; that is, the average land ownership is now <0.3 ha per farm household. Potentially, the total paddy field area in the country is now about 10.2 million ha, which is half of its wetland-irrigated paddy field. However, the official data (Ministry of Agriculture, 2009) show that the present rice-harvested area (year 2008) is totally 12.3 million ha: 11.2 million ha is wetland field and 1.1 million ha is dryland field. Also, the productions are 57.2 million and 3.2 million tonnes of rice (unhusked) for wetland and dryland fields, respectively. Almost no increment of harvested area as well as production of rice occurred in the country between 1997 and 2002. Meanwhile, there was about a 12% increment of harvested area and 15% of production occurred in the country between 2004 and 2008. This means that there is presently an average 3% annual growth of rice production in the country. However, comparing with the population growth, Figures 14.6 and 14.7 show that rice production per capita is stagnant, whereas the harvested area per capita tends to decrease.

According to the condition of agro-ecosystem and farm infrastructures, four types of farm fields can be recognized: irrigated, rainfed, flood-prone (marshland) and upland (dry). More than 80% of irrigated field can be cropped twice or more a year, whereas nearly 90% of non-irrigated field has only one crop a year. Technically-irrigated fields are mostly planted as monoculture by paddy for the whole year and it can be managed for two or three crops annually. Semi-technically and simply irrigated fields are mostly managed as rotated farming system, one or two crops by paddy and

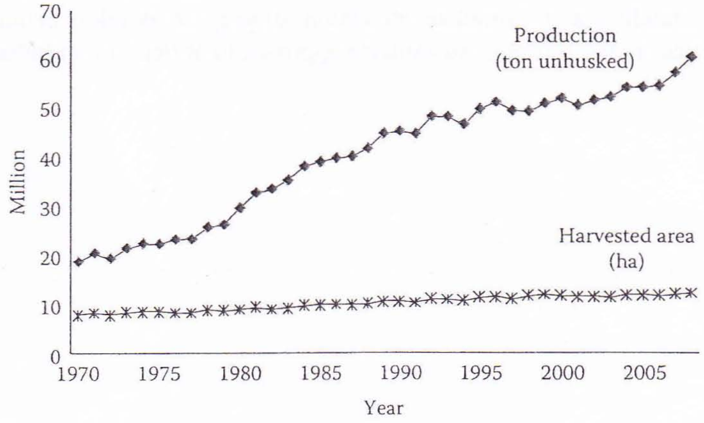


Figure 14.6 Domestic rice production and harvested area.

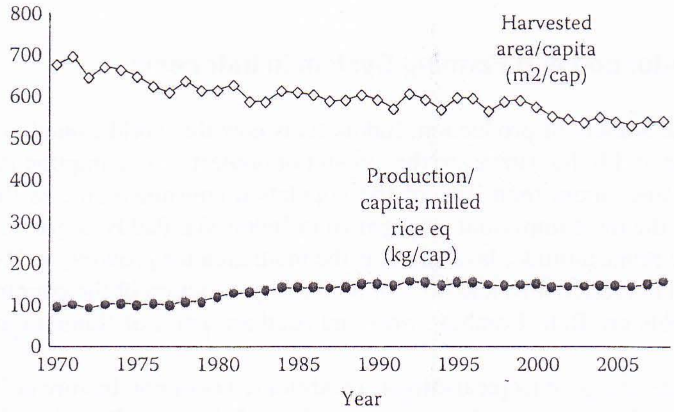


Figure 14.7 Per capita rice production and harvested area.

another one by secondary crops or vegetables. Table 14.3 shows the crop field area in Indonesia regarding the types of farming systems.

14.3.3 Organic Rice Production and Sustainable Agriculture

Despite diversity in agro-ecological conditions in Indonesian agriculture, it is useful to distinguish between agricultural problems related to intensive-irrigated areas and those related to extensive rainfed farming areas. Productivity has grown fastest in intensive-irrigated areas because of the increasing use of modern inputs such as irrigation water, chemical input of fertilizer and pesticide, and high-yielding variety and machinery. However, this system is associated with some environmental problems, that is, deterioration of water and soil quality, micronutrient deficiency and soil toxicity, weather and pest-related vulnerability, and loss of indigenous (traditional) varieties.

On the other hand, in the absence of an adequate increase of productivity in the less-productive rainfed agricultural area, farmers need to reduce fallows and expand into new areas. Sometimes they open a new fragile area with inappropriate land clearing, which causes pressure on the properties of natural resources and leads to degradation of environmental quality. Some major problems associated with extensive farming are loss of biodiversity, air pollution caused by slash and burn land opening, erosion, hillsides, drought and flood in lowland areas.

Concerning the present condition of agricultural practices in dealing with the needs to increase productivity and at the same time conserve the environment and natural resources, we need to adjust our understanding and formulate an action strategy to develop better and sustainable agricultural practices in the future. A sustainable approach to agriculture in Indonesia is necessary to keep increasing the productivity (to fulfil human needs), whereas at the same time it has to be in harmony with the environment (to maintain environmental balance). Furthermore, a sustainable agricultural system has to always take into account three dimensions of sustainability: economy, social and ecology.

Agricultural activities can basically result in both positive and negative effects in the environment. They vary significantly as a function of the type of production and management system. Environmental issues related to agricultural production and management practices include water quality and use, use and management of agricultural inputs (nutrients, pesticides and energy), land use and management, soil quality, biodiversity, climate and air quality. The organic farming system might be one of the most reasonable approaches to be disseminated to address the above-mentioned issues.

According to the latest report of Willer and Yussefi (2006), more than 31 million ha are currently managed organically by at least 623,174 farms worldwide. In Asia, the area under organic management has been comparatively small in the past years: the total organic area in Asia is now about 4.1 million ha, managed by almost 130,000 farms. The highest reported domestic market growth, estimated to be up to 30%, is in China and an organic boom seems to be taking place in Indonesia.

Organic agriculture in Indonesia is still in its infancy, although there is some sign that the movement may be in the take-off stage. The development so far is largely in the hands of farmers and the private sector while government supports have just started recently. The majority of organic producers are family farms with small land holdings and they are organized under grower group or organic projects. The predominant organic agriculture in Indonesia is rice crops and especially some vegetables.

The area under organic management in Indonesia is comparatively small; it is approximately only 0.2% of total agricultural land. However, according to IFOAM organic net (2008), organic management in Indonesia has been significantly increasing within the last 5 years: 17,800 ha in 2004, 40,400 ha in 2005, 52,882 ha in 2006 and 66,184 ha in 2007. Figure 14.8 gives the initial impression that Indonesia is at a good pace, being a big organic farming country in Asia. This fact will be more optimistic because the price of chemical fertilizers and pesticides is increasing and it will not be affordable anymore to most grassroot farmers.

Food quality and safety are now becoming of prime concern to customers along with the aim of protecting the environment through good practices of sustainable agriculture. These facts have been stimulating the demand for organic products and eventually have become the driving force in the

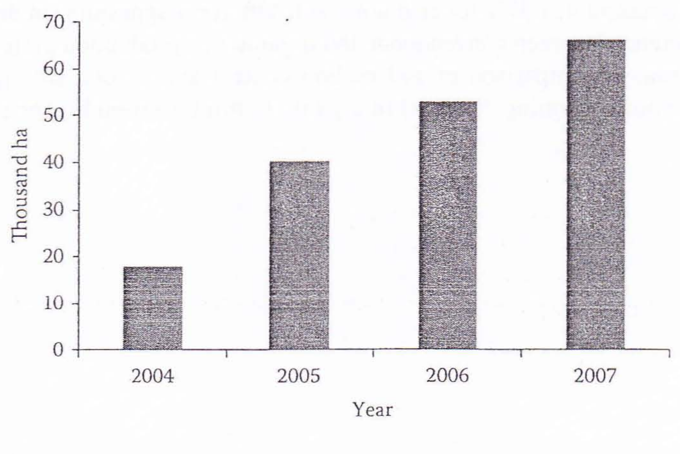


Figure 14.8 Area under organic farm in Indonesia. (Data from IFOAM Organic Net, 2008. Available at URL: http://www.organic-world.net. Accessed 15 March 2010.)

development of organic agriculture. Indonesian governments have responded by setting targets for the expansion of organic production, and new market opportunities have developed as part of the strategy to address such concerns.

With a population over 228 million people that is still growing, there is no doubt that organic agricultural products will have a market in Indonesia, now and in the future. The Indonesian government, as well as farmers' communities, has recently shown interest in organic farming with the expansion of the market for organic products and their potential for promoting sustainable agriculture. The department of agriculture established an ambitious programme, titled Go Organic, with the target of becoming one of the biggest producers of organic commodities in the world.

14.3.4 Organic Rice Production Practice in West Java, Indonesia

Organic farming provides several benefits to the farming system in Indonesia, because it can improve soil and food quality, and increase soil organic carbon (SOC) storage in the soil. For global environmental conservation, this soil management strategy has great potential to contribute to carbon sequestration, because the carbon sink capacity of the world's agricultural and degraded soil is 50–66% of the historic carbon loss of 42–72 petagrams (1Pg = 10^{15} g), although actual carbon storage in cultivated soil may be smaller if climate change leads to increasing mineralization (Lal, 2004). The importance of SOC in agricultural soil is, however, not controversial because SOC helps to sustain soil fertility and conserve soil and water quality, and these compounds play a variety of roles in nutrient, water and biological cycles.

Organic farming also has great potential in improving soil carbon storage (Pimentel et al., 1995; Marriott and Wander, 2006). However, only a few studies have been conducted in Indonesia, and there are few data for comparing soil carbon storage between organic farming and conventional farming. In addition, the organic farming system and associated farm work have not been studied in Indonesia. Therefore, this research was designed to evaluate the ability of soil carbon sequestration and make comparisons between the conventional farming system and the organic farming system for rice production on the island of Java.

The case study was observed in the city of Bogor, located in the Cisadane watershed, West Java, Indonesia. The Cisadane River flows through urban areas from Bogor to Jakarta, the capital of Indonesia, and is a major rice and vegetable production area. The soil type is Lotosole. Organic and conventional rice farmer groups for the study were selected from the Situgede district of Bogor.

For organic rice production in Bogor, farmers use a self-produced organic fertilizer called 'bochashi', which is composed of 10% rice bran, 20% rice chaff and 70% cow manure (in volume). Nutrient values of this organic fertilizer are 28.29% for carbon, 0.35% for nitrogen, 0.17% for phosphorus, 2.31% for potassium, 1.87% for calcium and 0.42% for magnesium (in dry base). Plate 14.2 illustrates the difference between conventional and organic rice production systems.

Figure 14.9 shows a comparison of soil carbon content and carbon storage in soil between organic and conventional farming. The soil in organic farming showed higher soil carbon content

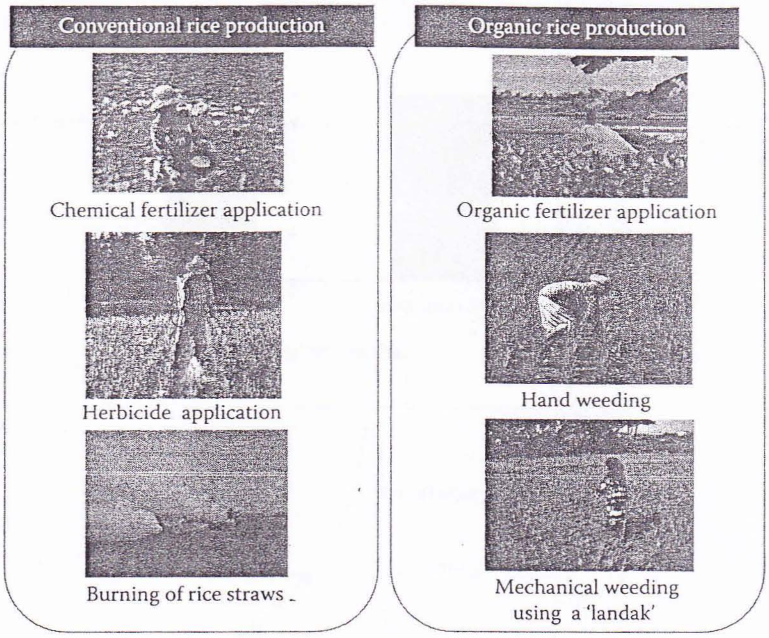


Plate 14.2 Comparison of farm work system between conventional and organic rice production in West Java, Indonesia.

that organic rice farming has a lot of potential in improving soil carbon sequestration and it may also mitigate global warming in Indonesia.

Figure 14.10 shows the costs for conventional and organic rice production. Organic farming helped in reducing the cost of rice production. For example, conventional farmers had to pay 1,410,000 Rp (rupiah, 1 US$ = 9,135 Rp) for chemical fertilizers, whereas organic farmers only had to pay 30,000 Rp for the *bochashi* organic fertilizer, with the result that organic farming could cut 90% of the total cost of rice production.

According to the latest data, the cost of farming with chemical fertilizers is on average twice as high as the use of organic products, although the production levels are the same, if not a fraction higher in the organic sector (*The Jakarta Post*, 2009). This indicates that the economic crisis helped boost the growth of Indonesia's organic farming sector.

Figure 14.10 also compares the labour inputs and methods of conventional and organic rice farming systems. The organic system required more labour to apply the organic fertilizer and weeding. The amount of organic fertilizer applied was 2 Mg/ha for each rice-growing season, which was 4 times greater than conventional farming due to the lack of appropriate technology for applying the organic fertilizer. Weeding in Indonesia is mainly done by hand, and while there are also traditional weeding tools called 'landak' (Plate 14.2), these tools still require a lot of manual labour. The total labour time for rice cultivation was 768 man hours/ha for the conventional system, whereas it was almost twice as high, 1406 man hours/ha, for the organic system.

Table 14.3 shows the gross profit and wages per working hour between the organic and conventional farming systems. The yield of organic farming was lower than in conventional farming, whereas the price of organic rice was 18% higher than conventionally grown rice, resulting in almost the same gross profits for organic and conventional farming. The wages per working hour in the organic system, however, were significantly lower, only about half those in the conventional system. The low labour productivity in organic farming is a major factor limiting the expansion of this farming system in West Java.

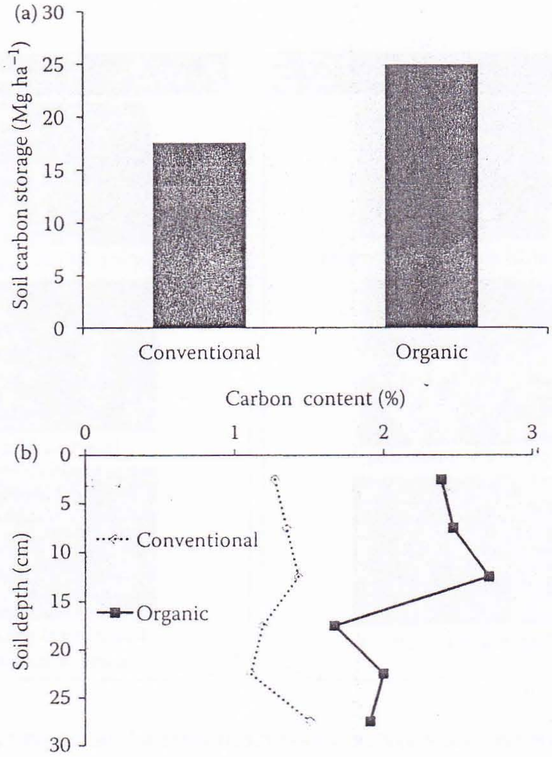


Figure 14.9 Comparison of soil carbon sequestration between organic and conventional rice fields in the top 10 cm soil depth (a) and soil carbon distribution (b). The different letters on the bar indicate the significant difference of soil carbon storage between organic and conventional rice fields ($P < 0.01$). (Data from Komatsuzaki, M. and M. F. Syuaib. 2010. *Sustainability* 2(3):833–843.)

According to the soil analysis, organic farming showed significantly higher SOC storage; hence it may help not only in mitigating global warming, but also in establishing a sustainable food system in Indonesia. Thus, organic farming will be one of the keys to establishing sustainable agriculture there. In Indonesia, organic farming for paddy rice cultivation also has a lot of potential to improve soil quality, reduce the cost of chemicals that have recently been increasing with the price of fossil fuels and increase farmers' incomes due to its higher price. However, organic farming requires intensive labour such as weeding and applying *bochashi* fertilizer to the fields.

The biggest difference was observed in the share-cropping system of organic farming in Indonesia compared with Japanese organic farmers. In the study area, profits from rice production were shared among the land owners, farmers (managers) and workers, but workers could receive

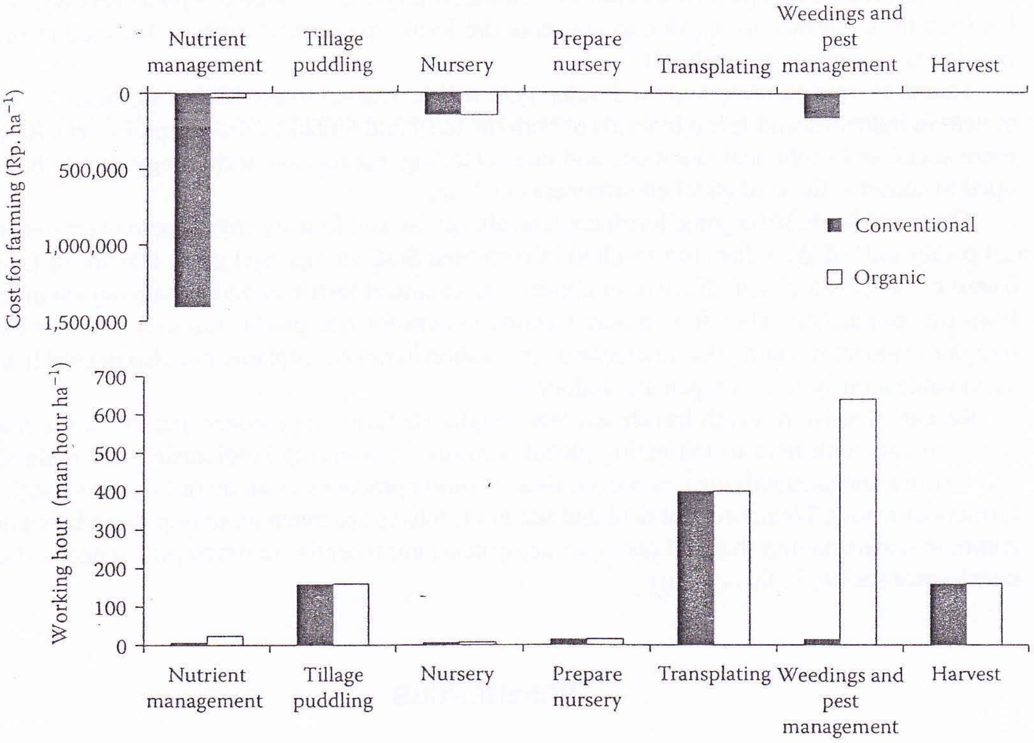


Figure 14.10 Comparison of costs for farming and man hours needed for each farming procedure between organic and conventional rice farming in West Java. (Data from Komatsuzaki, M. and M. F. Syuaib. 2010. *Sustainability* 2(3):833–843.)

in many parts of the world have begun to develop and promote sustainable agriculture. But adoption of sustainable farming is essential on a much larger scale to achieve the Millennium Development Goals on hunger, poverty and environmental sustainability in developing countries, and to sustain the ecosystem in rural economics in industrialized countries.

As local environmental quality becomes increasingly degraded by agricultural practices, the importance of protecting and restoring soil resources is being recognized by the world community (Lal, 1998, 2001; Barford et al., 2001). Sustainable management of soil received strong support at the Rio Summit in 1992 as well as at Agenda 21 (UNCED, 1992), at the UN Framework Convention on Climate Change (UNFCCC, 1992), in articles 3.3 and 3.4 of the Kyoto Protocol (UNFCCC, 1998), and elsewhere. These conventions are indicative of the recognition by the world community of the strong linkages between soil degradation and desertification on the one hand and loss of

Table 14.4 Comparison of Gross Benefit and Hourly Wages between Organic and Conventional Farming Systems

Management	Yield[a] (without husk) (Mg)	Price (Rp/kg)	Gross Benefits (Rp/ha)	Hourly Wages[b] (Rp)
Organic	3.2	6500	20,800,000	2955
Conventional	4.1	5500	22,550,000	5872

[a] Yields were obtained by quadrate sampling on September 2008.
[b] Hourly wages were calculated by taking account of the cost share of total benefit to the landowner, manager and worker.

biodiversity, threats to food security, increases in poverty, and risks of accelerated greenhouse effects and climate change on the other. This situation suggests that global support network systems between the countries are needed to conserve the local environment such as Indonesia's organic farmlands and Japanese croplands.

Therefore, new farming system development will be needed to establish a sustainable farming system in Indonesia and Japan in terms of both the local and global environmental levels. Based on these social and ecological situations and understanding, appropriate technology should be developed to conserve the ecological environments in Asia.

The use of *bochashi* organic fertilizer as an alternative soil fertility amendment in nutrient tropical paddy soils of West Java has resulted in increased SOC storage and gross benefit for farming. These techniques are also effective in eliminating chemical fertilizer and enhancing submaterials from rice production. Therefore, a new farming system for rice production may help not only in mitigating global warming due to carbon sequestration in the atmosphere, but also in establishing a sustainable food system in Japan and Indonesia.

Recent intensive research has shown that sustainable farming practices that use cover crops or bochashi can contribute to mitigating global warming, conserving biodiversity, and maintaining soil fertility and productivities. However, these farming practices often do not return enough for a farmers directory. Therefore, political and social incentives are much more important based on the common understanding that soil and agro-ecosystems are essential in developing a nature–human coexistence society in this century.

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