Assessment of Environment-friendly Rice Farming Through Life Cycle Assessment (LCA)

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ABSTRACT

To reduce the negative impacts of farming, both national and local governments in Japan are promoting environmentally friendly farming. Similarly sustainable agriculture practices are pursued in different parts of the world. Shiga prefecture (135° 52′ E, 35° 00′ N), Japan is promoting such environmentally friendly farming by providing subsidies to farmers who reduce the level of chemical fertilizer application to control water pollution and eutrophication in Lake Biwa basin. Environmental impacts of rice farming, particularly the emission of global warming gas (CO_2, N_2O, and CH_4), eutrophication (T-N and T-P and COD to water) and energy consumption, were analyzed by applying life cycle assessment (LCA), which is a method to analyze environmental impacts associated with whole process of certain product from raw material extraction, processing/production, distribution, use, and disposal. Cultivation practices and inputs (labor, materials, and chemicals) of farmers who adopt environmentally friendly and conventional practices were collected through interviews with local farmers in the basin of Nishinoko area in Shiga prefecture. The system boundary includes all processes of paddy production from seeding to harvest/drying and machinery/materials used for production, but does not include construction of facilities and buildings/land consolidation and waste disposal, distribution of products, and consumption processes. The process of making compost is also included in the analysis where compost is applied. Results show that environmentally friendly farming does not necessarily have lesser impacts when compared to conventional farming in different categories of assessment, which largely depends on the estimation of methane emission and total-P/total-nitrogen from paddy fields

Key words: Paddy production, Environmentally friendly farming, LCA, Global warming gas, Eutrophication

INTRODUTION

Sustainable agriculture and environmentally friendly farming have received wide attention and subsidies are being provided to encourage the adoption of good or environmentally friendly farming practices. In many cases, simply reducing the amount of chemicals (fertilizer, pesticides, insecticides/herbicide) is recognized as environmentally friendly. However, holistic assessment of farming is needed to check the sustainability of certain farming practices. For such examination, life cycle assessment (LCA) is often implemented to check the impacts of farming on environment (global warming, eutrophication, possible damage to living things). LCA is a method to analyze environmental impacts associated with whole process of certain product from raw material extraction, processing/production, distribution, use, and disposal. It is a useful tool in identifying an inventory of energy/material inputs and their environmental releases, analyzing the potential impacts, and establishing a sustainable system (NIAES, 2000, 2003; NIES, 2002).

Sustainability of different farming practices has been analyzed, particularly in Europe (Audsley et al., 1997; FAO, 2010; Nemecek et al., 2007). However, the study on rice farming in monsoon Asia is still in its infancy (Masuda, 2006). This paper analyzes the environmental impacts of rice farming by comparing conventional farming and environmentally friendly farming practices in Shiga prefecture, Japan, and identifies how to minimize environmental impacts of farming.

STUDY SITE AND METHODS

The study site is located in Asagoi district, in Shiga prefecture (Figure 1), where intensive rice farming is practiced. Rainfall during the growing season is 768 mm and the soil is fine gley soil with pH of 5.4-5.8, T-C 2.7-2.5%, T-N 0.19-0.18%, P2O5 25.8-28.5%, CEC 20.1-19.4 me, for conventional farming (CONV) and environmentally friendly farming (EFF), respectively.

To reduce the pollution and eutrophication, Shiga prefecture introduced a subsidy program to support EFF. Farmers who reduced chemical fertilizer inputs by more than 50% of CONV and adopted recommended practices (water saving puddling and others) are eligible to receive direct financial support as a compensation for the yield reduction and additional labor requirements.

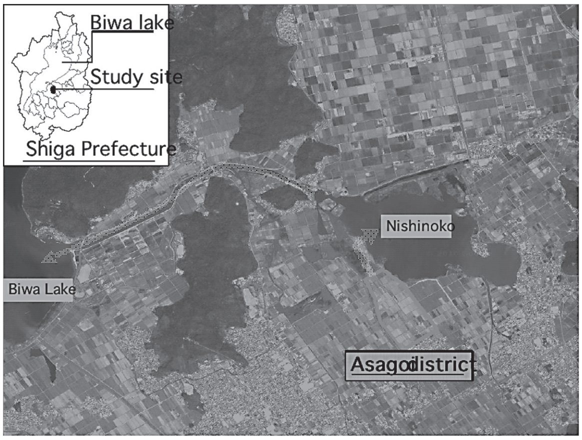


Figure 1. Location of the study site.

Table 1. Chemical and water inputs for EFF and CONV.

Inputs	T-N fertilizer (organic component) (kg/ha)	T-P fertilzer (kg/ha)	Chemicals (insecticide/ herbicide) (kg/ha)	Water consumption (mm)
CONV	76(0)	16	2.4	1,174
EFF	70 (55)	19	1.1	879

Source: Shiga Prefecture (2008)

Life cycle inventory (LCI) of farming practices and processing of rice farming was estimated using databases available in Japan including simple-LCA, 3EID (NIES, 2002), and CFP-Japan. In LCI, an inventory of flows from and to environment for the rice production was estimated, using field survey data and coefficients of discharge. Inventory flows include inputs (water, energy, chemicals, and materials), and releases to air, land, and water.

Rice plant absorbs carbon, however, they are discharged into the environment after the decomposition or rice consumption. As such, carbon discharge mostly came from the uses and the production of machinery/materials and chemicals. T-N absorption of rice plant was about 58 kg/ha (60% of total inputs and inflow) and 60 kg/ha (70 % of total inputs and inflow) for CONV and EFF, respectively, leaving about 20 kg/ha and 10 kg/ha of total-N into the environment. In case of T-P, absorption by rice plant was about 19 kg/ha for both farming practices, and the discharge out of the field was 3.4 kg/ha and 2.3 kg/ha, the discharge of EFF was about 32% lower than the CONV. Impacts on eutrophication is estimated using the loadings of T-N, T-P and COD with characterization factors of 3.06, 0.42, and 0.022, respectively (Shiga Prefecture, 2008).

LCA inventory analysis in this study focused on production and processing part, and did not take account of distribution or disposal. Inventory data was integrated using SimaPro 7.2 software by Pre-Consultant.

Rice yields were comparable level of 5.7 and 5.6 ton/ha for EFF and CONV, respectively, thus EFF was economically viable with reduced uses of chemicals and water consumption (25% water saving), although labor cost increased with additional labor requirements for spreading organic fertilizer and weeding.

In converting the results of LCI into LCA, "Ecological Scarcity Japan" method was adopted. This method was released in May, 2011 by Simapro. In this method, weightings of different impact categories were calculated based on the total present flows of an environmental pressure (LCI) and the maximum permissible flows of the same environmental pressure, taking account of the environmental policy goals or international agreements.

RESULTS

Estimates of green house gases (GHG) emission

Emission of carbon dioxide was assessed by farming processes such as the use of chemicals (fertilizer, insecticide), seedling production, machine operation/production energy, water pumping energy, and drying/threshing of rice (Dr/Th). Emission of methane mostly comes from decomposition of organic matter under intermittent irrigation after mid-summer drainage. Standard emission coefficient of 15.98 kg-CH_4/0.1 ha was used to calculate the methane emission. N_2O emission depends on the application of the N fertilizer component, and the standard emission coefficient of 0.0067 kg-N_2O/kg-N was applied.

Table 2 shows the emission of GHG by different farming practices with the share of each component in the bracket. CH_4 and N_2O emission were converted into CO_2 equivalent using the IPCC 4th report of global warming potential (GWP) coefficient of 25 and 298, respectively. CH_4 had the highest contribution to GW (global warming) with more than a 50% of CO_2 equivalent emission. Conventional farming had about 17% more discharge of GHG, which came from the use of chemicals, pumping energy and N_2O emission. EFF uses about 50% less Nitrogen fertilizer and other chemicals which reduced CO_2 emission during production of chemicals and NO_2 emission with less Nitrogen fertilizer. The difference in pumping energy came from the water savings of about 25% by shallow puddling water, and water saving management practices, including cycle irrigation, which is one of the requirements for receiving the subsidy under EFF.

Table 2. Emission of GHG by different farming practices. (Unit: kg-CO_2 equivalent (%)).

Process	CO_2					CH_4	N_2O	Total
	Chemicals	Seedling	Machine	Pumping	Dr/Th			
Conv	108.6 (13.5)	10.7 (1.3)	70.6 (8.8)	87.0 (10.8)	34.1 (4.2)	407.3 (50.7)	84.9 (10.6)	803.2
EFF	67.0 (9.8)	10.7 (1.6)	70.6 (10.3)	65.1 (9.5)	34.1 (5.0)	401.3 (58.5)	37.6 (5.5)	686.4

Conv = Conventional farming, EFF = Environmentally friendly farming, Dr/Th = Drying and Threshing.

If we assume, for example, the emission coefficient of 10 kg and 5 kg CH_4 emission per 0.1 ha from EFF and CONV farming, respectively, EFF will have about a 14 kg higher total CO_2-equivalent emission than CONV farming. As such, the outcome of the impact on GHG depends on how accurately we can estimate the emission of CH_4.

Impact on eutrophication

Total-N, Total-P and COD are used for calculating the impact on eutrophication by PO_4 -equivalent, with characterization values of 0.42, 3.06, and 0.022, respectively.

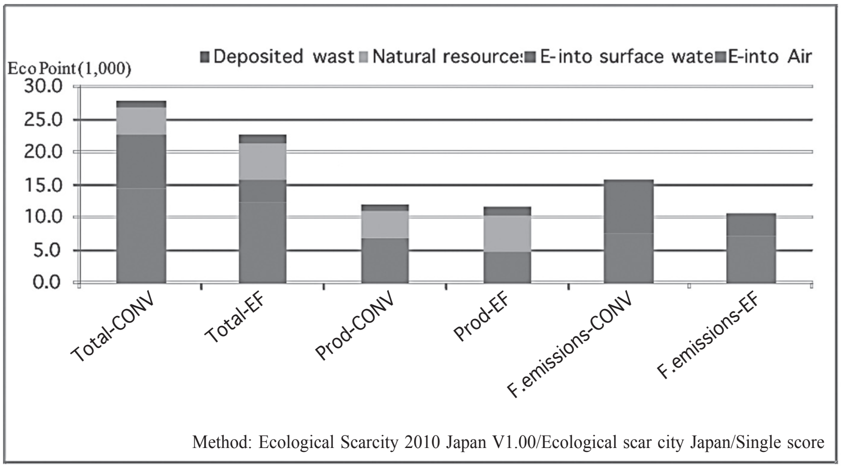
Table 3. Impact on eutrophication by different farming practices.

	Conventional	PO_4 equiv.	EFF	PO_4 equivalent
Total-N	2.05	0.86	1.00	0.42
Total-P	0.381	1.17	0.27	0.83
COD	21.5	0.47	8.93	0.20
Total		2.50		1.45

With a higher rate of fertilizer application by CONV, total impact on eutrophication is about 72% higher than EFF practice. In the calculation above, the reduction of drainage water with less water consumption by EFF is not taken into account. On average about 25% of water is saved by EFF. Thus, the total impact on eutrophication by EFF would be smaller than the calculation the above.

Overall environmental impact assessment

Results obtained by LCI and characterization are integrated into a single score (eco points) using normalization and weighting factors in “Ecological Scarcity Japan” method. Eco point is an artificial, unit-less score to allow the comparison of different units and systems. The result of weighting is shown in Figure 2. CONV had higher scores compared to EFF. However, the difference, which mostly originated in the discharge of nutrients (P and N from fertilizer) into surface water, was not so big. Impact from the production of agricultural machinery was excluded from the figure because the calculated impact score was only 200 points and was the same for Conv and EFF.



Prod- : impact by production process, **F.emissions-**: impact by field emission of gases

Figure 2. Comparison of LCA score by different farming practices.

More than 50% of the total impact came from the emission into air for both CONV and EFF practices, followed by emission into surface water and resources (energy, water, land, etc.) depletion.

DISCUSSION AND CONCLUSION

To establish sustainable farming, LCA is now applied to different types of farming and agriculture in general (Masuda, 2006; Ando, 2011; Hayashi, 2011). In this study, environmental impacts of different rice farming practices in Japan were analyzed using LCA method. In EFF practice, reductions in the amount of fertilizer/chemical inputs and the discharge of polluted agricultural drainage water are one of the requirements to be adopted to receive the subsidy from local government. In Shiga prefecture, Japan, EFF is now widely practiced with the encouragement of the local government and with supports from consumers.

In LCI analysis for rice production, the major contribution for GHG discharge came from the emission of methane gas from the rice field. Thus, the control of methane gas emission by decreasing the input of organic material or adopting intermittent irrigation practice is recommended. CONV and EFF practices did not show much difference in GHG category (CO_2 equivalent), because in Shiga prefecture, the input of chemical fertilizer had already been reduced to 70-90 kg-N/ha level (Shiga Prefecture, 2008). Similarly, in the eutrophication category, the discharge of phosphorous was the major contributor. However the analysis of the impact on the water body is limited to farming practice, and further elaboration in other processes including machine and chemical production would be needed.

To synthesize different impact categories, "Ecological Scarcity Japan" method, which was released in May, 2011 was applied. In this method, weightings of different impact categories were calculated based on the total present flows of environmental pressure and the maximum permissible flows of the same environmental pressure, taking account of the environmental policy goals. More than 50% of the total impact came from the emission into air for both CONV and EFF practices, followed by the emission into the surface water and the resources (energy, water, land, etc.) depletion. By implementing LCA analysis, the area of intervention can be easily identified to minimize the overall impacts of farming on the environment. Further elaboration of estimating the major emission and environmental pressure and accumulation of database of various farming materials/inputs and processes would be needed to improve the accuracy of the calculation.

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