Environmental Impacts on Concentrate Feed Supply Systems for Japanese Domestic Livestock Industry as Evaluated by a Life-cycle Assessment Method

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ABSTRACT : The objectives of this study were to evaluate and compare the environmental load of two different concentrate feed supply systems to the Japanese domestic livestock industry using the Life-cycle Assessment (LCA) method. The current system was defined as that requiring 11.469 million tons of corn imported from the US by sea transport and supplied as concentrate feed to the Japanese domestic livestock industry. The new system proposed by Kaku et al. in 2004 was defined as where 802,830 tons of US imported corn would not be planted in US and would be replaced by barley planted in 278 thousand ha of Japanese domestic land left fallow for the past year. In this case, 909,000 tons of domestic harvest barley would have been supplied as concentrate feed to the Japanese domestic livestock industry in 2000. The activities taken into account within the two system boundaries were three stages: concentrate feed production, feed transportation and gas emission from the soil by chemical fertilizer. Finished compost was regarded as organic fertilizer and was put instead of chemical fertilizers within the system boundary. Adoption of this new concentrate feed supply system by the Japanese domestic livestock industry could reduce 78,462 tons CO_2-equivalents of global warming potential, 347 tons SO_2-equivalents of acidification potential, 54 tons PO_4-equivalents of eutrophication potential and 0.842 million GJ as energy consumption below 2,000 levels. This LCA study comparing two Japanese domestic livestock concentrate feed supply systems showed that the stage of feed transport contributed most to global warming and the stage of emission from the soil contributed most to acidification and eutrophication. The Japanese domestic livestock industry could participate in emissions trading with CO_2-equivalents reduced by shifting from some imported US corn as a concentrate feed to domestic barley planted in land left fallow. In that case the Japanese government could launch emissions trading in accordance with Kyoto Protocol in the future. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 7 : 1022-1028)***

Key Words : Livestock, Barley, Concentrate Feed, Life-cycle Assessment, Greenhouse Gases, Emissions Trading

INTRODUCTION

Kyoto Protocol to the United Nations Framework Convention on Climate Change was adopted at the Third Conference of the Parties in 1997 and became effective since February 2005. Article Three stated that each Party to this Protocol should reduce carbon dioxide (CO_2) equivalent emissions of the greenhouse gases by at least 5 percent below 1990 levels in the commitment period 2008 to 2012. The Parties might participate in emissions trading for the purposes of fulfilling their commitments under Article Three. The Japanese government approved this protocol in 2002 officially. Therefore, the Japanese government should consider ways and means to elaborate the coordination of such policies and measures for enforcement of this protocol. It was rational that emissions of greenhouse gases from the Japanese domestic livestock industry might also be limited for the purpose of assuring compliance with commitments under Article Three in the near future.

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The Japanese domestic livestock industry had depended entirely on imported corn as concentrate feed, and this concentrate feed supply system was defined as the current system in this study. A new concentrate feed supply system was proposed by Kaku et al. (2004). This system supplies barley planted in Japanese domestic land left fallow as concentrate feed and thus we expected the barley planting could bring about an increase in the livestock feed self-sufficiency ratio and a decrease in domestic usage of US-imported corn as concentrate feed (Kaku et al., 2004). Emissions of greenhouse gases from the two different concentrate feed supply systems of the Japanese livestock industry should be estimated and compared to assure compliance with the Kyoto Protocol's requirements.

Methods for evaluating environmental problems had not yet been established. The internationally-standardized life-cycle assessment (LCA) method was expected to be highly effective for evaluations, and for assessing all the relevant environmental impacts at every stage in the life cycle of a product or activity. The environmental evaluations conducted for the livestock industry focused on the comparison of several systems, such as comparison of two different milk-production systems (de Boer et al., 2003), three farming systems (Hass et al., 2001), two different systems of dairy industry (Eide et al., 1998) and several Japanese beef-fattening systems with different feeding

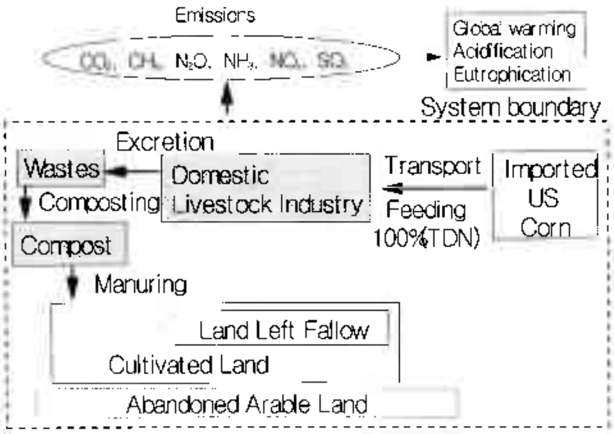

Figure 1. Description of the current concentrate feed supply system in this life-cycle assessment study. With this current system, the Japanese domestic livestock industry entirely depends on US imported corn as concentrate feed. Common processes showing diagonal area between two systems were not calculated.

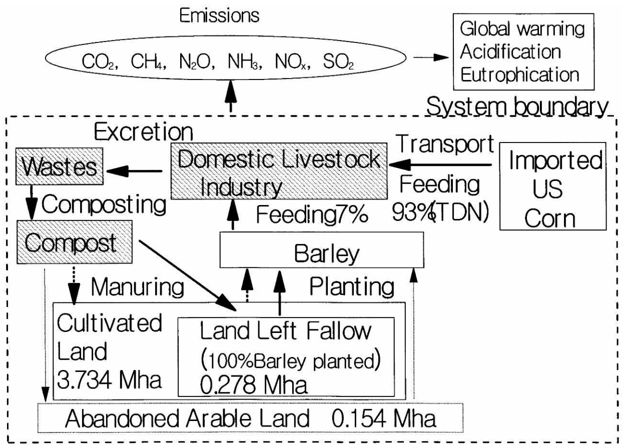

Figure 2. Description of the new concentrate feed supply system in this life-cycle assessment study. In case of conversion into TDN, 7% of US-imported corn would be replaced with barley planted in domestic land left fallow as concentrate feed to Japanese domestic livestock industry in 2000. Excessive livestock wastes-originated compost could have been used on either land left fallow or on abandoned arable land. Common processes showing diagonal area between two systems were not calculated.

lengths (Ogino et al., 2004). These studies showed that the LCA method could be applied for comparison of the different systems in the livestock industry.

However, no evaluation of the environmental impacts of concentrate feed supply systems to the Japanese livestock industry by the LCA method had been reported.

The objectives of this study were to evaluate and compare the environmental load of these two different concentrate feed supply systems to Japanese domestic livestock industry using the LCA method and to consider that the Japanese domestic livestock industry could participate in greenhouse gas emissions trading by adopting the above-mentioned new concentrate feed supply system proposed by Kaku et al. in the future.

This study is not just an example using a Japanese case, but indicates that this type of approach can be applied to other regions of the world.

MATERIALS AND METHODS

Life-cycle assessment is an ISO standardized method (ISO 14040-14043) for evaluating the environmental impact of a product, process, or activity throughout its life cycle. Life-Cycle Assessment methods are typically conducted using principles and guidelines laid out in ISO 14040-14043 (ISO 1440, 1997; ISO 14041, 1998; ISO 14042, 2000; ISO 14043, 2000). These break down the analysis into such sections as goal and scope definition, life-cycle inventory, life-cycle impact assessment and interpretation. The LCA was used to compare the environmental impact of different agricultural production systems, such as conventional and organic milk production (Cederberg et al., 2000; de Boer, 2003). Before discussing the LCA results from comparing the two different concentrate feed supply systems hereunder, the LCA framework was described as follows.

Definition of goal and scope (system description)

The first component of the LCA method was the definition of the goal and the scope of the analysis. The goal of this study was to evaluate the environmental impacts of two different concentrate feed supply systems to Japanese domestic livestock industry, and to consider the effects of emissions trading with the new concentrate feed supply system. The functional unit was defined as the total Japanese livestock industry with its concentrate feed supply system. Impact categories were global warming, acidification and eutrophication. The current and new systems analyzed in this study were presented in Figure 1 and 2. The current system was defined as the Japanese domestic livestock industry depending entirely on imported corn from the US, and all waste would be composted as fertilizer used on cultivated land, a system that would increase the risk of manure overload on land (Kaku et al., 2004). The current system was also defined as that requiring 11.469 million tons of corn imported from US by sea transport and supplied as concentrate feed to the Japanese domestic livestock industry. The new system, proposed by Kaku et al. in 2004, proposed that 802,830 tons of US imported corn need not be planted in US but rather would be replaced by barley planted in 278 thousand ha of Japanese domestic land left fallow for the past year enabling 909,000 tons of domestic harvest barley to be supplied as concentrate feed to the Japanese domestic livestock industry in 2000 (Kaku et al., 2004). The activities taken into account in the two systems were concentrate feed

Table 1. Environmental loads associated with Japanese domestic livestock industry feeding system

Source	Output coefficient	Reference
Feed production		
Energy use and relevant emissions	See text	Pimental (1980); JEMAI (2000)
NH_3 (from soil)	7.7% (NH_3-N)	Bouwman et al. (1997); Misselbrook et al. (2000)
N_2O (from soil)	0.5% (N_2O-N)	Eichner (1990)
Feed transportation		
Energy use and relevant emissions	See text	JEMAI (2000)

production, transportation, and gas emission from the soil by chemical fertilizer. Finished compost was regarded as organic fertilizer and was put instead of chemical fertilizers within each system boundary.

Life-cycle inventory

The second major step was to draw up an inventory of all the resources used and all the emissions released into the environment connected with defined activities within the system boundaries of Japanese concentrate feed supply systems. All the inputs and outputs associated with the concentrate feed supply system, such as feed production and feed transportation, were shown in Table 1. Data from the literature were used for specific activities for the concentrate feed supply systems, whereas the database of the LCA software JEMAI-LCA (JEMAI, 2000) was used for general activities, such as the production and combustion of fossil fuels and feed transport. Pollutants emitted from feed production were detailed by Ogino et al. (Ogino et al., 2004) and were determined as follows:

$$P_A = \sum_i D_i \times \left\{ \sum_j F_{ij} \times G_{Aj} + L_i \times M_A \right\}$$

P_A = emission of pollutant A from feed production, tons/year; Di = intake of feed *i*, tons/year; F*ij* = consumption of fuel *j* in production of feed *i* (MJ/tons of feed); G_{Aj} = emission coefficient of pollutant A from production and combustion of fuel *j* (tons/MJ); L*i* = consumption of electricity in production of feed *i* (GWh/tons of feed); M_A = emission coefficient of pollutant A from electricity production and consumption, tons/GWh; feed *i* = corn and barley; fuel *j* = gasoline, diesel, liquefied petroleum gas and indirect energy.

The weighted average of the coefficient of each fuel, based on the amount of consumption in the United States in 2000 (EIA, 2003), was used as the emission coefficient of pollutant from indirect energy, which was used to produce agricultural materials such as chemical fertilizers or pesticides.

Environmental loads from the feed transport were determined by multiplying unit emission by the product of the feed weight and transport distance. This was based on Japanese trade statistics and was defined as all concentrate feed imported as corn from the United States. The marine transport distance from the United States was defined as 18,180 km from New Orleans, LA to Nagoya, Japan and includes river freight shipped down the Mississippi River according to the JNOA distance chart (JNOA, 1990). The distances for land transport (trucking) in the United States and Japan were defined as 200 and 210 km, respectively.

Life-cycle impact assessment

To further interpret the data of the life-cycle inventory, it was necessary to evaluate the environmental impact associated with emissions and resource uses. In impact assessment, the data were interpreted in terms of their environmental impact. The environmental loads, which meant emissions and resources consumptions within system boundary, were sorted and assigned to specific environmental impact categories in the classification stage. Next came characterization, where the environmental loads were multiplied by equivalency factors for each specific load and impact category. Thereafter, all weighted environmental loads included in the impact category were added, and the resultant environmental impact was obtained.

In this study, the contribution of the two different concentrate feed supply systems to the following environmental impact categories were examined: global warming, acidification, eutrophication and energy consumption. The global warming potential, an index for estimating the global warming contribution due to atmospheric emission of greenhouse gases, was calculated according to the CO_2-equivalent factors given by IPCC (2001) for CO_2 = 1, CH_4 = 23 and N_2O = 296. To calculate the acidification potential of the different gases, the SO_2-equivalent factors for SO_2 = 1, NO_x = 0.7 and NH_3 = 1.88 derived from Heijungs et al. (1992) were used. To calculate the eutrophication potential, the PO_4-equivalent factors derived from Heijungs et al. (1992) for NO_x = 0.13 and NH_3 = 0.33 were used.

Interpretation

In the fourth phase of an LCA, the results of the LCA were used to identify possibilities of reducing the negative environmental effects of the systems and to verify that removals by the new concentrate feed supply system could reach such levels to allow participation in green house gases emissions trading in the near future. Results of this phase were described in the Discussion section.

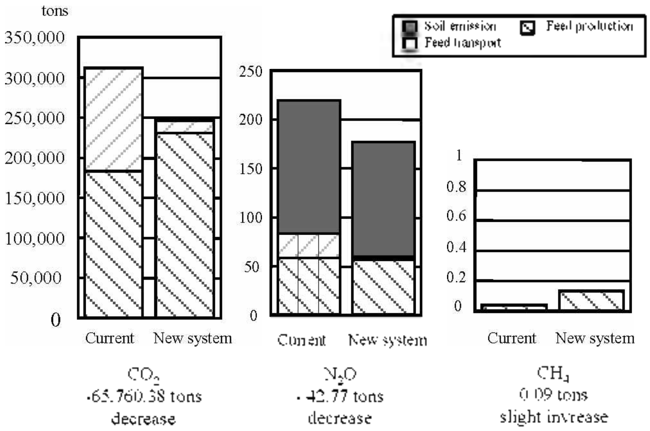

Figure 3. Comparison on the effect of global warming potential by changing from the current concentrate feed supply system to the new system. Calculations were practiced on different process between two systems. To calculate global warming potential, CO_2-equivalent factors were used: 1 for CO_2; 23 for CH_4 and 296 for N_2O. Production means corn production in US and barley production in Japanese fallow. Transport includes overseas and domestic transport. Soil emission means gas emission from the soil by chemical fertilizers.

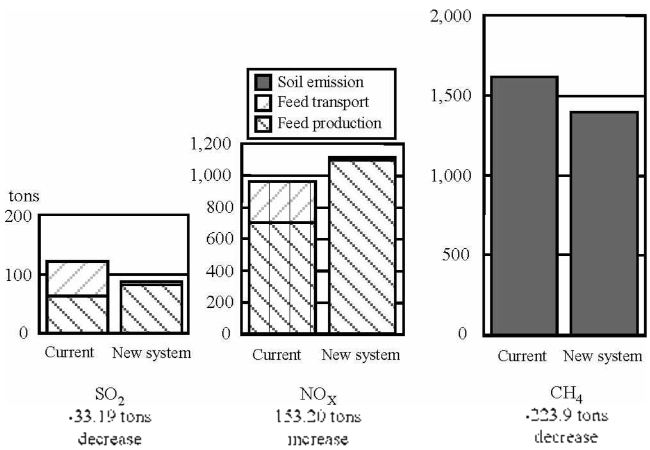

Figure 4. Comparison on effect of acidification by changing from the current concentrate feed supply system to the new system. Calculations were practiced on different process between two systems. To calculate acidification potential, SO_2-equivalent factors were used: 1 for SO_2, 0.7 for NO_X and 1.88 for NH_3.

RESULTS

Environmental impacts of concentrate feed supply systems for Japanese domestic livestock industry

We investigated the effects of changing from the current concentrate feed supply system to the new concentrate feed supply system to the Japanese domestic livestock industry on environmental impacts, which was proposed by Kaku et al. (2004). The comparison on contribution to global warming between the two systems was shown in Figure 3, if the new concentrate feed supply system were replaced with the current concentrate feed supply system. If the new

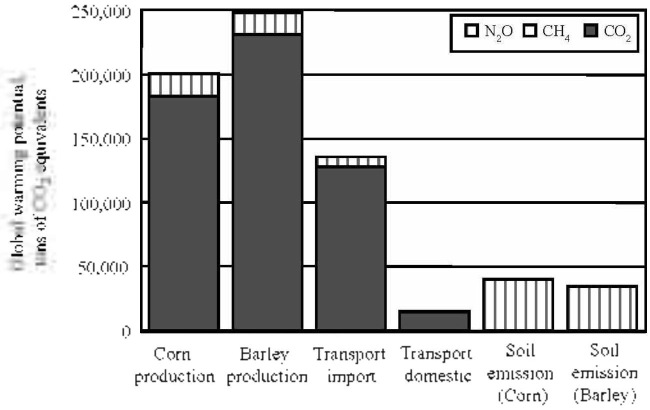

Figure 5. Contribution to global warming by each stage in the two concentrate feed supply systems. Calculations were practiced on different process between two systems. The functional unit is defined as total Japanese livestock industry with the two concentrate feed supply systems.

concentrate supply system were adopted instead of the current system, CO_2 emissions would decrease by 65,760.38 tons, N_2O emissions would decrease by 42.77 tons and CH_4 would increase by 0.09 ton. Therefore, 78,462 tons of CO_2 equivalents could be eliminated.

A comparison between the two systems on their contribution to acidification was shown in Figure 4. In case of the new concentrate supply system, SO_2 emissions would decrease by 33.19 tons, NO_X would increase by 153.20 tons and NH_3 decrease by 223.9 tons. Therefore, 347 tons of SO_2 equivalents could be eliminated.

Regarding eutrophication and energy consumption, the new concentrate feed supply system could eliminate 54 tons of PO_4 equivalents and 0.842 million GJ.

The contributions of each stage to global warming by the two concentrate feed supply systems were shown in Figure 5. The stages were: feed production, feed transport and gas emission from soil by chemical fertilizers. These data indicated that adopting the new system instead of the current system could reduce 120,305 tons of CO_2 equivalents from feed transport and 5,624 tons from gas emission from soil, but increase 47,467 tons from feed production. Therefore, transport by sea would contribute most to global warming among three stages, such as feed production, feed transportation, and gas emission from the soil caused by chemical fertilizers.

The contributions of each stage to acidification throughout the two concentrate feed supply systems were shown in Figure 6. These data indicated that adopting the new system could reduce 220 tons of SO_2 equivalents from feed transport and 421 tons from gas emission from soil, but increase 294 tons from feed production. Therefore, gas emission from soil caused by chemical fertilizers would contribute most to acidification among the three stages.

The contributions of each stage to eutrophication

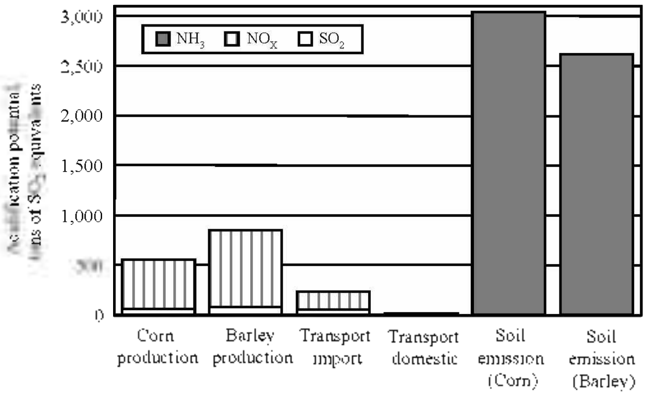

Figure 6. Contribution to acidification by each stage in the two concentrate feed supply systems. Calculations were practiced on different process between two systems. The functional unit is defined as total Japanese livestock industry with the two concentrate feed supply systems.

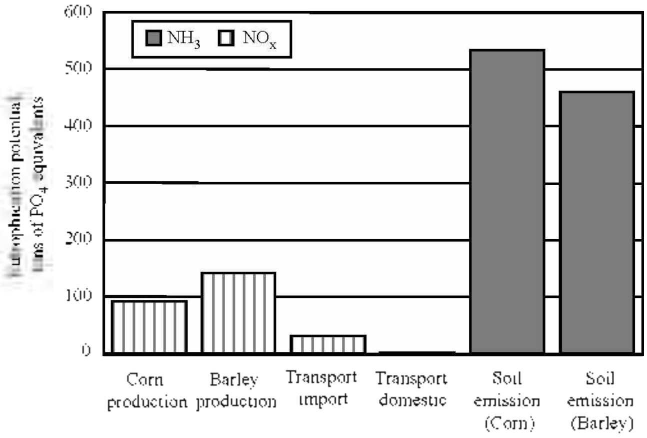

Figure 7. Contribution to eutrophication by each stage in the two concentrate feed supply systems. Calculations were practiced on different process between two systems. The functional unit is defined as total Japanese livestock industry with the two concentrate feed supply systems. To calculate eutrophication potential, PO_4-equivalent factors were used: 0.13 for NO_x and 0.33 for NH_3.

throughout the two concentrate feed supply systems were shown in Figure 7. This showed that adopting the new system could reduce 31 tons of PO_4 equivalents from feed transport and 74 tons from gas emission from soil, but increase 51 tons from feed production. Therefore, gas emission from soil caused by chemical fertilizers would contribute most to eutrophication among the three stages.

Changes in global warming potentials in Japan were shown in Table 2 resulting from calculations according to the greenhouse gases emissions data of Japan (Ministry of the Environment, 2004). Total contribution to global warming by the Japanese domestic livestock industry was 19,674,000 tons of CO_2-equivalents in 2002. Japanese domestic livestock industry and agricultural industry have already reduced CO_2-equivalents by 10% below 1,990 levels to Kyoto Protocol. But the total gas emission from Japan has increased CO_2-equivalents by over 9% above the 1990 levels set by Kyoto Protocol.

DISCUSSION

Evaluation of results and improvement assessment

Adoption of this new concentrate feed supply system could reduce CO_2-equivalents, SO_2-equivalents, PO_4-equivalents and energy consumption by the Japanese livestock industry.

This LCA study of the Japanese domestic livestock concentrate feed supply systems showed that the stage of feed production and feed transport contributed most to global warming, and the stage of emission from soil contributed most to acidification and eutrophication. CO_2 was a major pollutant in the categories of global warming, as shown in Figure 3 and 5. Ammonia was a major pollutant in the categories of acidification and eutrophication, as shown in Figure 4, 6 and 7. What is important is that adopting the new concentrate feed supply system could reduce 89% of CO_2 equivalents caused by feed transport.

Furthermore, in terms of global warming, the contribution of 78 thousand tons of CO_2 equivalents reduced by the choice of this new concentrate feed supply system could be converted to emissions trading in the near future. The Japanese government has already approved Kyoto Protocol and this protocol requires emissions trading on CO_2 equivalents. Therefore, the Japanese domestic livestock industry could participate in emissions trading by shifting concentrate feed from some of the imported US corn to domestic barley planted in land left fallow.

Advantages of the new concentrate feed supply system for the Japanese domestic livestock industry in addition to environmental benefits

In 2004, we reported that it would be beneficial to plant barley on domestic fallow land using manure as fertilizer, and to feed the livestock with the harvest (Kaku et al., 2004), i.e., the new concentrate feed supply system in this study. This study has already shown that the new concentrate feed supply system could reduce environmental loads, should the Japanese government adopt this new system. This new system has the following advantages in

Table 2. Global warming potential, CO_2-equivalent factors were used; 1 for CO_2, 23 for CH_4 and 296 for NO_2 (unit: 1,000 tons)

Year	1990	2002	2002/1990
Domestic livestock industry	22,037	19,674	89.28%
Domestic agricultural industry	59,655	53,597	89.84%
Total gas emission	1,187,751	1,302,795	109.68%

addition to the reduction of environmental loads.

One major benefit would be to slow the pace of cultivated land being left fallow. Furthermore, we expect planting barley could bring about an increase in the livestock feed self-sufficiency ratio. If barley had been planted in 100% of the land left fallow for the previous year in 2000, 4% of the nitrogen from livestock waste would have been utilized in the harvest, and the nitrogen-per-unit area would not have increased, but rather decreased from 125 to 121 N kg/ha during 1990-2000. Especially in fallow land, 59% of nitrogen from livestock, 20,000 tons out of 34,000 tons, would have been utilized as concentrate feed. Also, in case of conversion into TDN, 7% of the imported corn as concentrate feed could have been replaced with domestic harvested barley in 2000 (Kaku et al., 2004).

Emissions trading

Emissions trading has been already defined in Kyoto Protocol and is emerging as a key instrument in the drive to reduce greenhouse gas emissions. The rationale behind emissions trading supposes that the cost of reducing green house gas by emissions trading would be lower than any other emission-reduction schemes for combating climate change including overall costs.

UK Emissions Trading has already been launched by UK government since March 2002, and EU Emissions Trading is reported to start in January 2005 (Department for Environmental, Food and Rural Affairs [United Kingdom], 2002).

The UK emissions trading scheme was the world's first economy-wide greenhouse gas emissions trading scheme. Thirty-one organizations had voluntarily taken on emission-reduction targets to reduce their emissions against 1998-2000 levels as direct participants. These companies could use the scheme either to buy allowances to meet their targets, or to sell any over-achievement of these targets. Anyone could open an account on the registry to buy and sell allowances. The UK government reported that, in the first year, the Direct Participants achieved emission reductions of 4.64 million tons CO_2-equivalents against their baselines, and, in the second year, they have achieved emission reductions of nearly 5.2 million tons CO_2-equivalents against their baselines (Department for Environmental, Food and Rural Affairs [United Kingdom], 2002).

The Japanese government has not launched emissions trading yet in 2005, but is likely to create emissions trading in accordance with the Article 17 of Kyoto Protocol in the near future. When emissions trading starts in Japan, the Japanese livestock industry could participate in emissions trading and contribute 78,462 tons of CO_2-equivalents by adopting the new concentrate feed supply system in place of the current system.

IMPLICATIONS

This study not only showed one example from Japan, but implied that the Life Cycle Assessment method could be generalized to evaluate and compare environmental loads of agricultural systems all over the world. Kyoto Protocol has already become effective since February 2005. Therefore, CO_2-equivalents reduced within agricultural systems could be evaluated by Life Cycle Assessment method and globally sold in emissions trading in accordance with Kyoto Protocol.

REFERENCES

Bouwman, A. F., D. S. Lee, W. A. H. Asman, F. J. Dentener, K. W. Van Der Hoek and J. G. J. Oliver. 1997. A global high-resolution emission inventory for ammonia. Global Biochem. Cycles. 11:561-587.

Cederberg, C. and B. Mattsson. 2000. Life cycle assessment of milk production-a comparison of conventional and organic farming. J. Cleaner Prod. 8:49-60.

de Boer, I. J. M. 2003. Environmental impact assessment of conventional and organic milk production. Livest. Prod. Sci. 80:69-77.

Department for Environmental, Food and Rural Affairs (United Kingdom). 2001. UK Greenhouse Gas Emissions Trading Scheme 2002. London, United Kingdom.

EIA. 2003. Annual Energy Review. 2001. Energy Information Administration, U.S. Dept. of Energy, Washington, DC.

Eichner, M. J. 1990. Nitrous oxide emissions from fertilized soils: summary of available data. J. Environ. Qual. 19:272-280.

Eide, M. H. and T. Ohlsson. 1998. A comparison of two different approaches to inventory analysis of dairies. Int. J. LCA. 3:209-215.

Hass, G., F. Wetterich and U. Kopke. 2001. Comparing intensive, extensified and organic grassland farming in southern Germany by process life cycle assessment. Agric. Ecosyst. Environ. 83:43-53.

Heijungs, R., J. Guinee, G. Huppes, R. M. Lankreijer, H. A. Udo de Haes, A. Wegener Sleeswijk, A. M. M. Ansems, P. G. Eggels, R. Van Duin and H. P. De Goede. 1992. Environmental life-cycle assessment of products-Guide. Center of Environmental Science (CML). Leiden Univ., Leiden, The Netherlands.

IPCC. 2001. Climate Change 2001: The Scientific Basis. Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Port Chester, NY.

ISO. 1997. Environmental management-Life cycle assessment: Principle and framework. ISO 14040. Int. Standards Org., Brussels, Belgium.

ISO. 1998. Environmental management-Life cycle assessment: Goal and scope definition. ISO 14041. Int. Standards Org. Brussels, Belgium.

ISO. 2000a. Environmental management-Life cycle assessment: Life cycle impact assessment. ISO 14042. Int. Standards Org. Brussels, Belgium.

ISO. 2000b. Environmental management-Life cycle assessment: Life cycle interpretation. ISO 14043. Int. Standards Org., Brussels, Belgium.

JEMAI. 2000. JEMAI-LCA. Japan Environ. Manag. Assoc. Indust., Tokyo, Japan.

JNOA. 1990. World-Wide Distance Chart. 3rd ed. Japan Navigating Officers`Association, Kaibundo, Tokyo, Japan.

Kaku, K., A. Ikeguchi, A. Ogino, T. Osada, M. Hojito and K. Shimada. 2004. Achieving a nitrogen balance for Japanese domestic livestock waste: Testing the scenario of planting feed grain in land left fallow. Asian-Aust. J. Anim. Sci. 17:1026-1032.

Ministry of the Environment (Japan). 2004. Statistics of Environment (2004). 46-53. Tokyo, Japan.

Misselbrook, T. H., T. J. Van Der Weerden, B. F. Pain, S. C. Jarvis, B. J. Chambers, K. A. Smith, V. R. Phillips and T. G. M. Demmers. 2000. Ammonia emission factors for UK agriculture. Atmos. Environ. 34:871-880.

Ogino, A., K. Kaku, T. Osada and K. Shimada. 2004. Environmental impacts of the Japanese beef-fattening system with different feeding lengths as evaluated by a life-cycle assessment method. J. Anim. Sci. 82:2115-2122.

Pimental, D. 198990. Handbook of Energy Utilization in Agriculture. CRC Press, Boca Raton, FL.

United Nations. 1997. Kyoto protocol to the United Nations framework convention on climate change. NY. USA.