Asian-Aust. J. Anim. Sci.
Vol. 22, No. 2 : 216 - 224
February 2009

www.ajas.info

# Application of a Simulation Model for Dairy Cattle Production Systems Integrated with Forage Crop Production: the Effects of Whole Crop Rice Silage Utilization on Nutrient Balances and Profitability

**K. Kikuhara and H. Hirooka***

Laboratory of Animal Husbandry Resources, Graduate School of Agriculture
Kyoto University, 606-8502 Kyoto, Japan

**ABSTRACT :** In Japan, since rice consumption has been decreasing with the westernization of Japanese eating habits, surplus paddy fields have been increasing. If these surplus paddy fields can be utilized for forage rice production as feed for animal production and excretions (feces and urine) from animal production can be applied to the paddy fields as manure, then the problems of surplus paddy fields and excretions from animal production may be solved, and the environment kept sustainable. The objectives of the present study were to apply a bio-economic model to dairy and forage rice integration systems in Japan and to examine the merit of introducing whole crop rice silage (WCRS), as well as economic and environmental effects of various economic and management options in the systems. Five simulations were conducted using this model. The use of WCRS as a home-grown feed increased environmental loads and decreased economic benefit because of the higher amount of purchased feed, when compared to the use of typical crops such as maize, alfalfa and timothy silage (simulation 1). Higher economic benefits from higher forage rice yields and higher milk production of a dairy cow were obtained (simulations 2, 3). There were no economic and environmental incentives for utilizing crude protein (CP) rich WCRS, because an increase in the CP content in WCRS led to the use of more chemical fertilizers, resulting in high production costs and nitrogen outputs (simulation 4). When evaluated under the situation of a fixed herd size, increasing forage rice yields decreased the total benefit of the production, in spite of the fact that the amount of subsidies per unit of land increased (simulation 5). It was indicated that excess subsidy support may not promote yield of forage rice. It was, however, observed in most cases that dairy and forage rice integration systems could not be economically established without subsidies. (**Key Words :** Forage Rice, Whole Crop Rice Silage, Dairy Cattle, Whole Farm, Simulation Model, Subsidy)

## INTRODUCTION

Rice is a staple food for the Japanese and other Asians and plays an integral role in the socio-economy and culture of Asian countries (Islam et al., 2004). In addition, paddy fields have played many functions, including retaining the groundwater level, controlling air temperature and preventing floods, all of which are critical to making the environment sustainable. However, as there has been less rice consumption than production during the last decade (except in 1993) (MAFF, 1994), Japan does not need to grow excess rice any more, and thus about one-third of the paddy fields remain set aside at present, which is a potential loss both economically and environmentally (Islam et al., 2004).

* Corresponding Author: H. Hirooka. Tel: +81-75-753-6363, Fax: +81-75-753-6373, E-mail: hirooka@kais.kyoto-u.ac.jp
Received February 8, 2008; Accepted October 4, 2008

On the other hand, in Japan, huge amounts of animal feeds, including forage, have been imported from the USA and other countries during the past few decades, indirectly contributing to the drop of self-sufficiency for feed. Intensified animal production leads to excessive excretions such as feces and urine, which results in nutrient imbalances and thus serious environmental problems. At present, 14 % of the TDN requirement of dairy cattle depends upon imported forage, which is higher than for other domestic animal species.

In recent years, integration between dairy and forage rice production has been encouraged by the Japanese government. Use of whole crop rice silage (WCRS) as feed for dairy cattle would be a step forward in enhancing self-sufficiency of feed, and the application of manure from dairy cattle to the paddy fields would be desirable to maintain paddy fields and minimize environmental problems (Kusa et al., 2006). Nevertheless, since forage rice

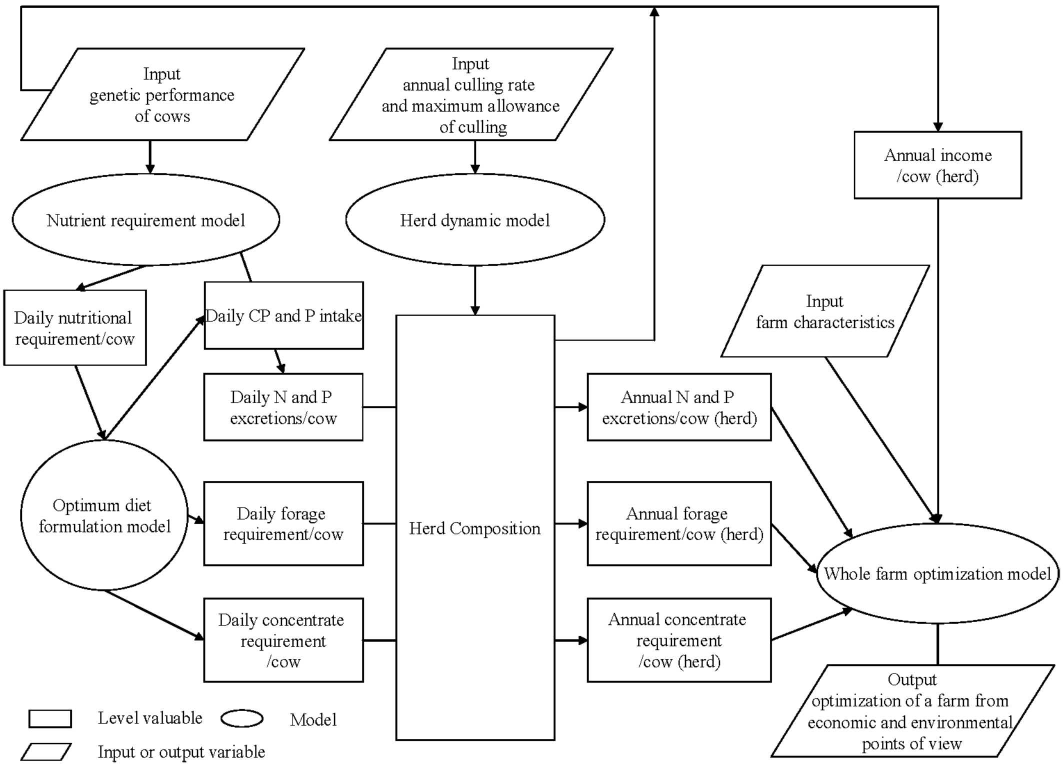


**Figure 1.** Overview of the bio-economic model for Japanese dairy farms.

production is still a start-up system and requires an immense amount of time and effort to grow compared to conventional home-grown feed, the Japanese government supports farmers who adopt integration systems by giving three kinds of subsidies in order to promote the use of WCRS.

In general, integrated dairy and forage rice production systems are complex, consisting of various nutritional, management and economic factors and their interactions. Systems approaches with simulation models allow analysis of the behavior of such complex systems and demonstrate the advantages and disadvantages of forage rice production in the system. Kikuhara et al. (2008) developed a bio-economic simulation model to evaluate dairy and forage crop integration systems in Japan. The objectives of the present study were to apply the bio-economic model to dairy and forage rice integration systems in Japan, to examine the merits of introducing WCRS, and to examine the economic and environmental effects of various economic and management scenarios in the systems.

## MATERIALS AND METHODS

A simulation study was conducted to illustrate the consequences of feed management on farm nutrient loading and profitability. The effects of alternative management practices were evaluated on a representative farm in the northern part of Honshu area.

### Bio-economic simulation model for Japanese dairy farms

All simulations were performed using a bio-economic simulation model for Japanese dairy farms (Kikuhara et al., 2008), which illustrates the interactions of an integrated farming system (dairy and forage production systems). An overview of the model structure is illustrated in Figure 1. The model consists of four sub-models: the nutrient requirement model, the optimum diet formulation model, the herd dynamic model, and the whole farm optimization model.

The nutrient requirement model was constructed based on the Japanese Feeding Standards for dairy cattle (MAFF, 1999) and used to predict metabolizable energy requirements (ME), crude protein (CP), dry matter intake (DMI), calcium (Ca), phosphorus (P) and vitamin A (VA).

The optimum diet formulation model determined the optimum diet that meets nutrient requirements for the lowest cost using linear programming. In this model, it was assumed that the price of home-grown feed was zero. This assumption automatically led to the promotion of the use of home-grown feed. In recent times, the Japanese government has encouraged utilization of home-grown feed to increase the self-sufficient rate of feed production.

The herd dynamic model calculated the number of cows

**Table 1.** Nutritive values* (Dry matter (DM), metabolizable energy (ME), crude protein (CP), calcium (Ca), phosphorus (P), and vitamin A (VA)) contained in each feed used in this study

| Nutritive value | Purchased feed | | | | | | | Home-grown feed | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Corn | Barley | Soybean cake | Mineral mix | Beet pulp | Bran | Alfalfa hay cube | Timothy silage | Alfalfa silage | Maize silage | Whole crop rice silage (WCRS) |
| DM (kg/kg) | 0.87 | 0.88 | 0.88 | 0.10 | 0.87 | 0.87 | 0.89 | 0.30 | 0.24 | 0.26 | 0.37 |
| ME (Mcal/kg) | 3.09 | 2.84 | 2.95 | 0.00 | 2.44 | 2.41 | 1.79 | 0.73 | 0.49 | 0.65 | 0.75 |
| CP (g/kg) | 80 | 106 | 461 | 0 | 109 | 157 | 147 | 46 | 39 | 21 | 26 |
| CP(% of DM) | 9.2 | 12.0 | 52.2 | 0 | 12.6 | 17.7 | 16.5 | 13.7 | 16.1 | 8.0 | 6.9 |
| Ca (g/kg) | 0.26 | 0.62 | 2.91 | 22.00 | 5.11 | 1.13 | 11.86 | 1.47 | 4.04 | 0.74 | 0.70 |
| P (g/kg) | 2.68 | 3.35 | 6.18 | 10.00 | 0.78 | 9.57 | 2.58 | 0.90 | 0.65 | 0.71 | 0.80 |
| VA (1,000 IU/kg) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 11.60 | 4.80 | 3.87 | 4.43 | 7.46 |

* These nutritive values are reported in GAFSA (2006) and NARO (2001).

in each reproductive cycle at equilibrium. This model was constructed based on Hirooka et al. (1998). It was assumed that the herd size is stable, all replacement heifers are home grown, heifers are culled when they failed to conceive and cows that failed to conceive are culled at the end of lactation.

The whole farm optimization model integrated outputs from the above three sub-models and determined the effects of animal performance and management practices on farm behaviors, production efficiencies, and nutrient losses to the environment. In this sub-model, the objective function was to maximize yearly net profit and the elements were dairy cows, feed production, purchased fertilizer, labor and surpluses of nitrogen and phosphorus.

Nutrient flows through the farm were modeled to predict potential nutrient accumulation and loss to the environment. The nutrient content of the manure produced was a function of the quantity and nutrient content of the feeds consumed (Kikuhara et al., 2008). All excretions were used to produce manure to apply to cultivated land as organic fertilizer. The manure N and P applied to land were less effective than chemical fertilizer because of their lower fertilizer-N and -P equivalency (Kikuhara et al., 2008). The amounts of effective N and P in manure were derived by considering lower efficiency of manure and emission of N as ammonia.

This model can be used annually to find an optimum combination of feed resources that minimize feed cost, to simulate critical elements of the complex interactions between a system's components and to predict the effects of alternative management decisions on farm profitability and the environment within the existing framework.

**The representative farm and model assumptions**

A hypothetical farm was modeled to represent typical dairy farms in the northern part of Honshu. The farm was on 18.4 ha of land. In the first simulation (simulation 1), use of whole crop rice silage (WCRS) as feed for dairy cattle (defined as base scenario) was evaluated by comparing with a case for the use of general forage crops (control scenario). In the control scenario, maize and pastures (timothy and alfalfa) were harvested as silage. The parameters including fertilizing and labor requirements, and the production yield for these home-grown feed in the control scenario were obtained from Kikuhara et al. (2008). In the base scenario, forage rice was harvested and given to dairy cattle in the form of whole crop rice silage (WCRS). The nutritive values contained in each feed used for the structuring of the optimal ration are shown in Table 1. The fertilizer requirements of forage rice production for nitrogen (N) and phosphorus (P) in the base scenario were 120 kg N/ha and 17.46 kg P/ha (NARC, 1997; NARO, 2003). Furthermore, in this model, it was assumed that the fertilizer requirements of forage rice production varied with the yield levels of forage rice. Considering the amount of N and P uptake from crops, the fertilizer requirements of forage rice at each yield level were obtained as:

$$N_{req} = 120 + (DMY - 8{,}000) \times CP_{WCRS} / 6.25$$

$$P_{req} = 17.46 + (DMY - 8{,}000) \times P_{WCRS}$$

where $N_{req}$ and $P_{req}$ are N and P requirements (kg/ha), DMY is the dry matter yield of forage rice (kg DM/ha), and $CP_{WCRS}$ and $P_{WCRS}$ are crude protein (CP) and P contents in WCRS (kg/kg DM). The annual base yield of forage rice was assumed to be 8,000 kg DM/ha (GAFSA, 2006).

The labor requirement was set as 78.3 h/ha for forage rice production (NARO, 2006). It was assumed that the price of home-grown feed was zero. This assumption automatically led to the promotion of the use of home-grown feed. All excretions were used to produce manure to apply to cultivated land as organic fertilizer. Excess manure was assumed to be surplus and exported from the farm.

For the performance of the dairy cows, annual milk production was set at 8,400 kg/cow as a basis. The composition of a cow population was determined by the culling rate of females (LIAJ, 2007): heifers and cows that failed to conceive were culled in each reproductive cycle

**Table 2.** Economic parameters and prices* assumed in comparison between the two scenarios for management practice guideline (control scenario) and use of WCRS (base scenario)

| Parameter | Control scenario | Base scenario |
|---|---|---|
| Buying price of feed (yen/kg) | | |
| Corn | 36.18 | 36.18 |
| Barley | 44.74 | 44.74 |
| Soybean cake | 62.23 | 62.23 |
| Mineral mix | 425 | 425 |
| Beet pulp | 47.97 | 47.97 |
| Bran | 30.95 | 30.95 |
| Alfalfa hay cube | 51.04 | 51.04 |
| Fertilizer price** (yen/kg) | 95.34 | 95.34 |
| Milk price (yen/kg) | 89.1 | 89.1 |
| Selling price of animals | | |
| Calf (yen/animal) | 38,458 | 38,458 |
| Culled cow (yen/kg) | 150.8 | 150.8 |
| Annual home-grown feed production cost*** (yen/ha) | | |
| Maize | 151,775 | |
| Timothy | 77,715 | |
| Alfalfa | 55,577 | |
| Forage rice | | 241,830 |
| Labor wage rate (yen/h) | 1,612 | 1,612 |

* Economic parameters and prices are reported in MAFF (2005abc).
** Fertilizer includes 0.15 N/kg and 0.15 P/kg.
*** Home-grown feed production cost is calculated as total feed production cost minus fertilizer cost, labor cost, fixed costs, and land cost. MAFF (2005c).

(Kikuhara et al., 2008).

Prices were set to reflecting long-term relative values of farm inputs and outputs in yen. Prices and economic parameters are listed in Table 2 (MAFF, 2005abc).

**Simulation designs**

Five simulations were performed using a bio-economic simulation model (Kikuhara et al., 2008) for Japanese dairy farms to determine the impact of system changes on forage rice production, feed use, milk production, manure production, nutrient surpluses, production costs and net farm return (Table 3). The simulations 1 to 4 were conducted under the situation of a fixed land size (18.4 ha), whereas simulation 5 was under the situation of a fixed herd size (47 cows).

In the first simulation (simulation 1), the impact of WCRS introduction (base scenario) was compared with the management practice guideline (control scenario) given by Kikuhara et al. (2008). All farm parameters were held constant except for the type of home-grown feed (use or non-use of WCRS).

In the second simulation (simulation 2), the effects of forage rice yield were examined. Assuming the technical and genetic improvements, the yield of forage rice was increased from 8,000 kg DM/ha to 16,000 kg DM/ha in steps of 2,000 kg DM/ha.

**Table 3.** Constraints and variables for simulations

| Constraint and variable | Simulation 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Constraint | | | | |
| Land | +* | +* | +* | |
| Herd | | | | +* |
| Variable | | | | |
| Forage rice yield | +* | | | +* |
| Milk yield | | +* | | |
| WCRS CP content | | | +* | |
| Subsidy | | | | +* |

* Represents that constraints or variables were considered in each simulation.

In the third simulation (simulation 3), the effects of changes in the milk yield (MY) of dairy cows were examined. Simulations were done with ±5% and ±10% change in the assumed value from the annual MY (8,400 kg/cow).

In the fourth simulation (simulation 4), the effects of improving the CP contents of WCRS were examined. The CP content of WCRS (CP = 6.9% DM) was comparably lower than that of other feeds (GAFSA, 2006). Therefore, CP-rich WCRS was simulated with all other nutritive parameters kept constant: an existing CP-rich WCRS (CP = 8.4% DM) reported in the literature (KONARC, 2003) was assumed.

In the final evaluation (simulation 5), the impacts of forage rice yield and subsidies (from 0 yen/ha to 100,000 yen/ha) on net profit were examined under the situation of a fixed herd size. At present, in Japan, there are three kinds of subsidies relating to dairy farming systems that use WCRS. All subsidies are given to farmers, depending on a basis of the land area of forage rice that they cultivate. In this situation, a higher forage rice yield would lead to a reduction in land area utilized. This reduction caused both positive and negative impacts on farm profitability since all subsidies were supported depending on the area of the land. Therefore, this simulation enabled examination of the impact of subsidy on profit when the herd size (the number of cows) was fixed but land areas differed.

## RESULTS AND DISCUSSION

**Comparison with the control scenario (simulation 1)**

In the first simulation, the utilization of WCRS as home-grown feed was compared with the control scenario shown in Kikuhara et al. (2008) (Table 4). The purchased feed cost in the base scenario was higher than in the control scenario. This increase in purchased feed cost was due to lower nutritive values in WCRS. To fulfill the nutritional requirements of the animal, the model compensated for the quality and quantity of the diet by increasing the amounts of purchased feed. This result indicates that utilization of

**Table 4.** Effects of increasing forage rice yield on annual production, nutrient balance, production costs, and net return (simulation 1, 2)

| Production or cost parameter | Control scenario | Forage rice yield | | | | |
|---|---|---|---|---|---|---|
| | | Base scenario (8,000 kg DM/ha) | 10,000 kg DM/ha | 12,000 kg DM/ha | 14,000 kg DM/ha | 16,000 kg DM/ha |
| Number of cows (cows) | 43 | 47 | 58 | 71 | 83 | 95 |
| WCRS intake (kg DM/animal) | | 2,271 | 2,271 | 2,271 | 2,271 | 2,271 |
| Purchased feed cost (yen/animal) | 123,268 | 160,637 | 160,637 | 160,637 | 160,637 | 160,637 |
| Manure fertilizing (kg N) | 3,494 | 3,666 | 4,582 | 5,499 | 6,415 | 7,332 |
| Chemical fertilizing (kg N) | 900 | 1,108 | 1,238 | 1,368 | 1,498 | 1,646 |
| N surplus (kg/ha) | 33 | 248 | 303 | 357 | 411 | 466 |
| Revenue (yen) | 28,921,160 | 31,220,330 | 39,025,420 | 46,830,500 | 54,635,580 | 62,440,670 |
| Total cost (yen) | 22,013,330 | 30,049,800 | 36,581,660 | 43,113,520 | 49,645,380 | 56,188,940 |
| Net profit (yen) | 6,907,830 | 1,170,530 | 2,443,760 | 3,716,980 | 4,990,200 | 6,251,730 |

WCRS as feed leads to an increase of purchased feed. It is therefore suggested that utilization of WCRS instead of other home-grown forage crops might be not a solution for raising feed self-sufficiency rate in Japan. Moreover, a higher number of cows and higher amount of purchased feed in the base scenario resulted in higher N surplus.

Most production costs increased with a larger herd size. Labor and fixed costs all increased with more feed fed and more cows milked in the base scenario. Feed cost increased considerably, but revenue also increased with more milk and animals sold. Overall, farm net profit in the control scenario was higher, since both the home-grown production and purchased feed costs in the base scenario were higher.

**Increased forage rice yield (simulation 2)**

Increased forage rice yield greatly increased animal density, environmental impacts, revenue, production costs and net return (Table 4). Increasing number of cows on the same land area increased animal density. With more animals and forage rice yield on the farm, larger amounts of forage, grain and chemical fertilizer were purchased. The increases in purchased feed and chemical fertilizer led to much greater nutrient loading on the farmland. As a result, N surplus resulted from higher forage rice yield on a land unit basis.

Most production costs increased with the larger herd size. Labor and fixed costs all increased with more feeds fed and more animals milked. Feed cost increased considerably, but revenue also increased with more milk and animals sold. Overall, farm net profit was improved. Therefore, the increase in forage rice yield, which resulted in the increase in animal numbers per unit of land area, enhanced profitability but caused the increase in environment load.

It was indicated that, in all cases, the net profit obtained from use of WCRS was lower than that obtained in the control scenario and thus WCRS utilization was difficult to establish without any subsidies in this type of situation. The effect of the subsidy will be investigated later in simulation 5.

**Altered milk yield of a dairy cow (simulation 3)**

The simulation assumed that milk yield (MY) of a dairy cow can be altered by genetic and nutritional improvement.

The N surplus was slightly sensitive to changes in MY. Increasing MY caused rises in both the input and output of N of the production systems. This was because more purchased feed was required and more milk was sold. On the other hand, the higher nutrient inputs from the purchased feed increased the amount of excretions for use as manure. Consequently, more manure was supplied. Assuming that the total fertilizer requirement was constant, a rise in the purchased feed intake reduced chemical fertilizer requirement. As a result, when the milk production level increased (decreased) 5% and 10%, approximately 4% and 9% more (less) N was applied as manure, respectively (Table 5).

Economic variables were sensitive to changes in MY. The high sensitivities of revenue and total cost were expected, since milk sales provided the highest income. An increase in MY led to a rise in the revenue via a rise in milk sales (Table 5). To fulfill the higher nutritional requirements of the animals caused by higher MY, the model compensated for the quality and quantity of the diet by increasing the amounts of purchased feed, which increased total cost. When the milk production level increased (decreased) 5% and 10%, the purchased feed cost became approximately 3% and 6% higher (lower), respectively (Table 5). Totally, the increment in revenue was higher than that in total cost, providing a positive net profit for the farm.

**Use of CP rich-WCRS (simulation 4)**

Although most of the current forage rice varieties contain relatively low crude protein (CP), this may be enhanced by genetic improvement of the varieties. It was therefore assumed in this simulation that a CP-rich WCRS

**Table 5.** Effects of altered milk production (changed ±5% and ±10% from the assumed value of annual milk yield (8,400 kg/cow)) on annual production, feed use, nutrient balance, production costs, and net return (simulation 3)

| Production or cost parameter | Milk yield | | | | |
|---|---|---|---|---|---|
| | 7,560 kg (-10%) | 7,980 kg (-5%) | Base scenario (8,400 kg) | 8,820 kg (+5%) | 9,240 kg (+10%) |
| Number of cows (cows) | 47 | 47 | 47 | 47 | 47 |
| WCRS intake (kg DM/animal) | 2,269 | 2,272 | 2,271 | 2,267 | 2,260 |
| Purchased feed cost (yen/animal) | 147,049 | 153,775 | 160,637 | 167,632 | 174,753 |
| Manure fertilizing (kg N) | 3,466 | 3,563 | 3,666 | 3,776 | 3,894 |
| Chemical fertilizing (kg N) | 1,168 | 1,139 | 1,108 | 1,133 | 1,040 |
| N surplus (kg/ha) | 236 | 242 | 248 | 255 | 262 |
| Revenue (yen) | 28,324,290 | 29,749,200 | 31,220,330 | 32,742,000 | 34,317,780 |
| Total cost (yen) | 29,237,270 | 29,619,580 | 30,049,800 | 30,527,530 | 31,052,090 |
| Net profit (yen) | -912,980 | 129,620 | 1,170,530 | 2,214,470 | 3,265,690 |

**Table 6.** Effects of use of CP-rich WCRS on purchased feed composition (simulation 4)

| Purchased feed | Base scenario (CP = 6.9% DM) | Use of CP-rich WCRS (CP = 8.4% DM) |
|---|---|---|
| Corn | 1,621 | 1,715 |
| Barley | 0 | 0 |
| Soybean cake | 589 | 519 |
| Mineral mix | 77 | 78 |
| Beet pulp | 0 | 0 |
| Bran | 367 | 326 |
| Alfalfa hay cubes | 359 | 359 |

(CP = 8.4% DM) would be available. The result showed that use of CP-rich WCRS led to reduction of the intakes of other CP-rich feeds such as soybean cake and bran (Table 6). This was because more CP was supplied from the CP-rich WCRS. In contrast, the ME-rich but lower CP content feed such as corn was fed to compensate for reduction of energy intake by less ME and CP-rich feeds (soybean cake and bran).

There was little difference in N surplus since fewer CP-rich feeds and more chemical fertilizer were purchased when CP-rich WCRS was utilized (Table 7). Purchased feed costs per animal were slightly less (1%) than those in the base scenario. Most production costs slightly increased with lower purchased feed costs and higher chemical fertilizer costs, and thereby farm revenue decreased because of slight reduction (47.26 head to 47.14 head) in the number of cows, providing a negative net return for the farm. This reduction in the number of cows was due to the increased WCRS intake per animal. Net profit decreased by 99,930 yen (-7%) by utilizing the CP-rich WCRS. This simulation showed that there were no economic and environmental incentives for improving WCRS CP content because more fertilizers (N) would be required on the cultivated land.

**Impacts of forage rice yield and subsidies under the fixed herd size situation (simulation 5)**

Increment in forage rice yield under the situation of a fixed herd size (47 cows) increased animal density and environmental impacts but decreased production costs which resulted in a rise in net profit (Table 8).

At the increased yield of forage rice with the same herd size, despite unchanged revenue, home-grown feed production costs decreased since less land was required, providing the increment in net profit. That is, the increase in the forage rice yield, which resulted in a reduction in cultivated land area, enhanced profitability but increased the potential degradation of the environment caused by higher animal density.

Considering the subsidies, however, the results were totally changed. When the amount of subsidies increased according to land size, the benefits obtained from subsidies

**Table 7.** Effects of use of CP-rich WCRS on annual production, feed use, nutrient balance, production costs, and net return (simulation 4)

| Production or cost parameter | Base scenario (CP = 6.9% DM) | Use of CP-rich WCRS (CP = 8.4% DM) |
|---|---|---|
| Number of cows (cows) | 47 | 47 |
| WCRS intake (kg DM/animal) | 2,271 | 2,277 |
| Purchased feed cost (yen/animal) | 160,637 | 158,891 |
| Manure fertilizing (kg N) | 3,666 | 3,658 |
| Chemical fertilizing (kg N) | 1,108 | 1,424 |
| N surplus (kg/ha) | 248 | 248 |
| Revenue (yen) | 31,220,330 | 31,148,820 |
| Total cost (yen) | 30,049,800 | 30,078,220 |
| Net profit (yen) | 1,170,530 | 1,070,600 |

**Table 8.** Effects of increasing forage rice yield on annual production, nutrient balance, production costs, and net return under the situation of a fixed herd size (47 cows) and varied land areas (simulation 5)

| Production or cost parameter | Forage rice yield | | | | |
|---|---|---|---|---|---|
| | Base scenario (8,000 kg DM/ha) | 10,000 kg DM/ha | 12,000 kg DM/ha | 14,000 kg DM/ha | 16,000 kg DM/ha |
| Land (ha) | 18.4 | 14.7 | 12.3 | 10.5 | 9.2 |
| WCRS intake (kg DM/animal) | 2,271 | 2,271 | 2,271 | 2,271 | 2,271 |
| Purchased feed cost (yen/animal) | 160,637 | 160,637 | 160,637 | 160,637 | 160,637 |
| Manure fertilizing (kg N) | 3,666 | 3,666 | 3,666 | 3,666 | 3,666 |
| Chemical fertilizing (kg N) | 1,108 | 990 | 912 | 856 | 823 |
| N surplus (kg/ha) | 248 | 303 | 357 | 411 | 466 |
| Revenue (yen) | 31,220,330 | 31,220,330 | 31,220,330 | 31,220,330 | 31,220,330 |
| Total cost (yen) | 30,049,800 | 28,620,530 | 27,667,680 | 26,987,080 | 26,482,470 |
| Net profit (yen) | 1,170,530 | 2,599,800 | 3,552,650 | 4,233,250 | 4,737,860 |

for higher forage rice yield decreased (Figure 2). At a lower subsidy level, increased forage rice yield promoted net profit. In contrast, however, at a higher subsidy support level, increased forage rice yield led to a reduction in subsidy support due to less land area for production of forage rice, resulting in the negative impact on net income. This situation occurred in this study because subsidies were supported depending on the utilized land area in the current Japanese policy. This result indicates that excess subsidy per unit of land would not promote forage rice yield when the herd size is fixed.

## Concluding remarks

It was observed in this study that forage rice utilization could not be economically established without subsidies in most cases. In simulation 1, dairy producers who utilize WCRS could maintain their farming systems only by being supported more than 31,181 yen/10a (Table 4). Simulation 2 showed that the net profit was lower than that obtained in the control scenario until the forage rice yield was increased to 16,000 kg DM/ha. Therefore, subsidies would be needed for forage rice production, as long as much more technological and genetic improvement for forage rice yield was not realized.

There are three kinds of subsidies relating to the dairy farming systems using forage rice. The first subsidy is for feeding WCRS to dairy cattle. Since the use of WCRS as feed is still unfamiliar to dairy producers, the Japanese government strongly recommends and encourages forage rice utilization by supporting dairy producers with subsidies. The second subsidy is for nutrient recycling. To enhance the application of animal excretions as manure to crop fields and thereby nutrient cycling within a farm, the subsidy has been supported for both dairy and rice producers who

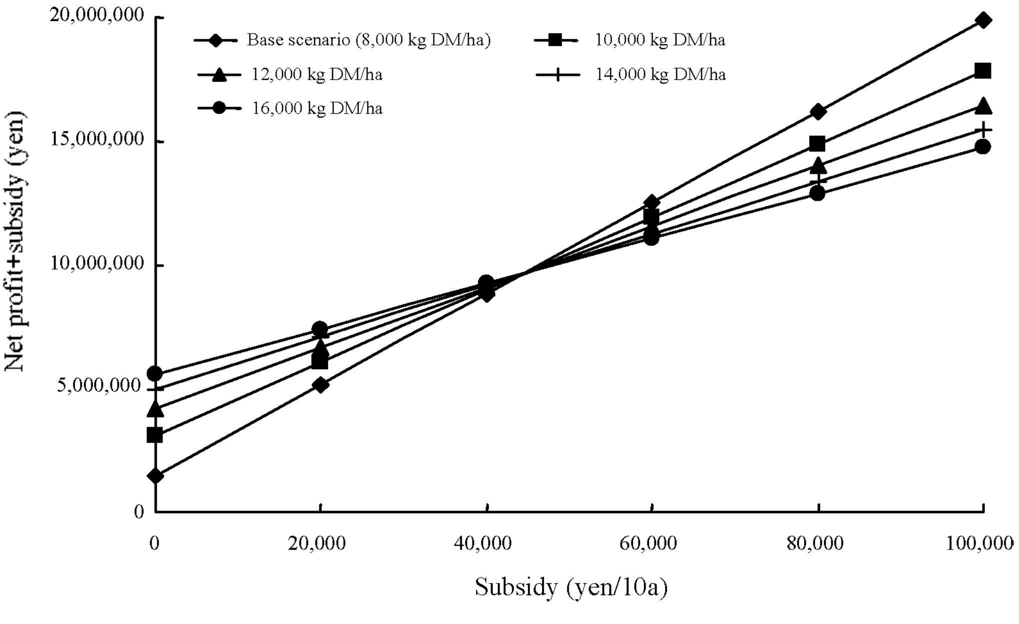


**Figure 2.** Effects of forage rice yield and various levels of subsidy supports on farm return under the situation of a fixed herd size (47 cows).

decide to grow forage rice, produce WCRS, and use he WCRS. The last subsidy is a crop changeover encouragement subsidy. This subsidy has been supported for rice producers who grow forage rice in their paddy fields. Paddy rice cultivation was first subjected to cutbacks in 1970 because of oversupply, when 236,000 hectares of paddy field were set aside. The fallow field has steadily increased and therefore about 37% of the total paddy field was taken out of cultivation in 2002. As a consequence, much of this land has been planted with other crops, mostly vegetable and fruit trees. In a decade, however, a forage production system has been originally established for making use of fallow fields derived from crop changeover policies.

MAFF (2006) and NARCT (2004) pointed out that rice producers grow forage rice for the increase of their profitability by supported subsidies. Therefore, it has been stated by the Japanese government that these subsidies should reduce in the near future (MAFF, 2006). The impacts of a reduction in subsidies on farm management have already been investigated by several simulation studies (NARO, 2006). MAFF (2006) suggested that higher forage rice yield is an important option for promoting forage rice production in Japan. This simulation also illustrated that there was an economic incentive for improving the forage rice yield when the level of subsidy support was low.

Another option that can resolve this problem would be to convert the subsidy system from a land area basis to a yield basis (NARO, 2006). If this kind of subsidy system were introduced, dairy cattle production systems integrated with forage rice production would be more popular in Japan, because more profit will result from higher forage yield under such a subsidy system.

## ACKNOWLEDGEMENT

This work was supported in part by a Grant-in-aid (Integrated research for developing Japanese-style forage feeding system to increase forage self-support ratio) from the Ministry of Agriculture, Forestry, and Fisheries of Japan (JFS-08-26006-3).

## REFERENCES

GAFSA. 2006. Technical manual for whole crop rice silage production and feeding. Japan grassland agriculture and forage seed association, Tokyo, Japan (in Japanese). Available from: http://souchi.lin.go.jp/skill/report/01.html. Accessed 11 January 2008.

Hirooka, H., A. F. Groen and J. Hillers. 1998. Developing breeding objectives for beef cattle production. 1. A bio-economic simulation model. Anim. Sci. 66:607-621.

Islam, M. R., M. Ishida, S. Ando, T. Nishida and N. Yoshida. 2004. Estimation of nutritive value of whole crop rice silage and its effect on milk production performance by dairy cows. Asian-Aust. J. Anim. Sci. 17:1383-1389.

Kikuhara, K., H. Kumagai and H. Hirooka. 2008. Development and evaluation of a simulation model for dairy cattle production systems integrated with forage crop production. Asian-Aust. J. Anim. Sci. 22:57-71.

KONARC. 2003. Nutrient composition for forage rice collected in Kyusyu region. National Agricultural Research Center for Kyushu Okinawa region, Kumamoto, Japan (in Japanese). Available from: http://konarc.naro.affrc.go.jp/kyusyu_seika/2003/2003257.html. Accessed 13 January 2008.

Kusa, K., T. Ishikawa, K. Abe, M. Ishida and T. Saikusa. 2006. Effects of the continual application of cattle manure compost on whole crop yield and nutritive values of forage rice (*Oryza Sativa L.*). AAAP Animal Science Congress 2006, C05-PP-020, Korea.

LIAJ. 2007. Distribution of testing cows by parity. 2005. Livestock Improvement Association of Japan (in Japanese). Available from: http://liaj.lin.go.jp/japanese/kentei/ke0532.html. Accessed 15 October 2007.

MAFF. 1999. Japanese feeding standard for dairy cattle. 1999. Agriculture, Forestry and Fisheries Research Council Secretariat, Ministry of Agriculture, Forestry and Fisheries, Livestock Industry Association, Tokyo, Japan (in Japanese).

MAFF. 2005a. Basic plan for modernization of dairy and beef cattle production. Ministry of Agriculture, Forestry, and Fisheries, Tokyo, Japan (in Japanese). Available from: http://www.maff.go.jp/lin/pdf/03-01rakuniku.pdf. Accessed 5 October 2007.

MAFF. 2005b. Survey statistics on prices in agriculture. Ministry of Agriculture, Forestry, and Fisheries, Association of Agriculture and Forestry Statistics, Tokyo, Japan (in Japanese).

MAFF. 2005c. Production costs of animal products. Ministry of Agriculture, Forestry, and Fisheries, Tokyo, Japan (in Japanese). Available from: http://www.tdb.maff.go.jp/toukei/a02smenu4?TokID=E009&TokKbn=B&TokID1=E009B2004-002&TokID2=E009B2004-002-005&TokID3=E009B2004-002-005-001#TOP. Accessed 21 October 2007.

MAFF. 2006. Feeding cattle with rice. Agriculture, Forestry, and Fisheries Research Council, Ministry of Agriculture, Forestry, and Fisheries, Tokyo, Japan (in Japanese). Available from: http://www.s.affrc.go.jp/docs/report/report15/no15.pdf. Accessed 21 December 2007.

NARC. 1997. Estimation of $P_2O_5$ and $K_2O$ absorption by paddy rice for revising fertilization standard. National Agricultural Research Center, Ibaraki, Japan (in Japanese). Available from: http://www.affrc.go.jp/seika/data_narc/h09/narc97S099.html. Accessed 6 January 2008.

NARCT. 2004. Current status of forage rice production and farmers' intent. National Agricultural Research Center for Tohoku region, Iwate, Japan (in Japanese). Available from: http://www.agri-ex.pref.akita.jp/plan/jihou/44/h16jihou18.pdf. Accessed 23 December 2007.

NARO. 2001. Standard tables of feed composition in Japan. 2001. National Agricultural Research Organization, Tokyo, Japan (in Japanese).

NARO. 2003. Characteristics for cultivating the rice breed

"Hoshiaoba". National Agricultural Research Organization, Ibaraki, Japan (in Japanese). Available from: http://www.naro.affrc.go.jp/top/seika/2003/kanto/kan03022.html. Accessed 5 January 2008.

NARO. 2006. Meeting for "Managerial Evaluations and Establishment Conditions of Forage Rice Production and Utilization Technology". National Agricultural Research Organization, Ibaraki, Japan (in Japanese).