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Article

A New Strategy for Utilizing Rice Forage Production Using a No-Tillage System to Enhance the Self-Sufficient Feed Ratio of Small Scale Dairy Farming in Japan

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Abstract: Rice forage systems can increase the land use efficiency in paddy fields, improve the self-sufficient feed ratio, and provide environmental benefits for agro-ecosystems. This system often decreased economic benefits compared with those through imported commercial forage feed, particularly in Japan. We observed the productivities of winter forage after rice harvest between conventional tillage (CT) and no-tillage (NT) in a field experiment. An on-farm evaluation was performed to determine the self-sufficient ratio of feed and forage production costs based on farm evaluation of the dairy farmer and the rice grower, who adopted a rice forage system. The field experiment detected no significant difference in forage production and quality between CT and NT after rice harvest. However, the production cost was dramatically decreased by 28.1% in NT compared with CT. The self-sufficient ratio was 5.4% higher when dairy farmers adopted the rice forage system compared with those using the current management system. Therefore, this study demonstrated the positive benefits for dairy farmers and rice growers in Japan when adopting a rice forage system with NT, which could improve the self-sufficient feed ratio and reduce production costs.

Keywords: dairy farming; forage production; no-tillage; rice forage system; self-sufficient ratio

1. Introduction

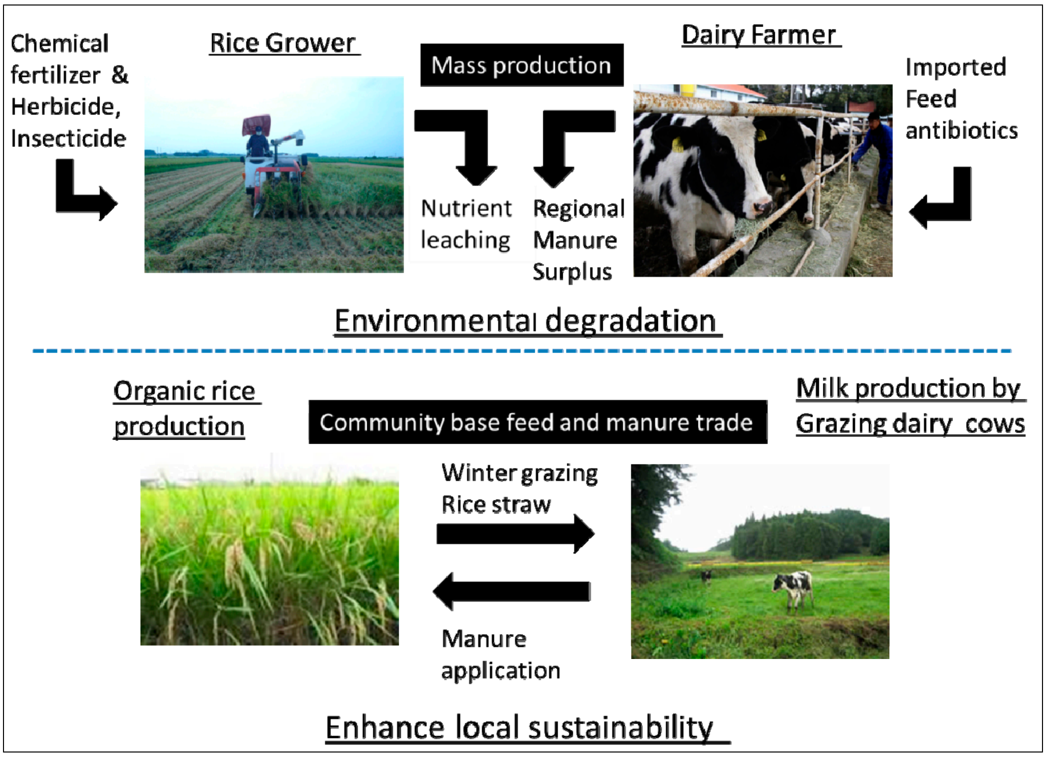
In Japanese dairy farming, the self-sufficient feed ratio, which was measured by the ratios of domestic and imported feed in the total consumed feed for dairy farming [1], has slowly declined each year at the domestic level, and the current ratio is only 22%, which is a 3.13% decrease over the years 2006–2011 [2]. In contrast, the high level of feed import has increased the production costs for dairy farming in Japan, and threatened the sustainability of rural communities. Due to the forage scarcity on a global scale in the coming decades [3], increasing the self-sufficient ratio (SSR) could help to achieve sustainable dairy farming practices in Japan.

Adopting the rice forage system may improve the SSR. Paddy fields are abundant sources of forage production for dairy cattle. Rice forage was one of the major farming systems in the Kanto area in the 1960s. This system had several benefits for rice and dairy farmers, as rice farming produces several by-products, such as rice straws and rice chaffs, which are suitable feed materials for dairy farming. Dairy farming also provides manure for paddy fields, which helps to maintain the soil quality in paddy fields.

However, increases in the scale of dairy and rice production have led to the disappearance of rice forage systems because of the dominance of mechanized and specialized farming systems, which depend on concentrated and imported hay feed for dairy farming and chemical fertilizers for rice cultivations. These changes have been disadvantageous for the environment and have reduced sustainability. For example, excess livestock manure application to small grasslands has caused considerable nutrient leaching into water [4], while indoor feeding systems have increased the stress for dairy cattle, thereby reducing milk production and damaging their health [5].

A system based on grazing in paddy fields during the winter season would enhance forage production in the community and reduce negative local environmental effects because it would reduce nitrogen leaching from the fields in the early spring, when nitrogen leaching is considerable [6]. This grazing system could also improve herd health and the environment, as well as confer economic advantages during cattle production [7]. Grazing of paddy fields makes better use of ecosystem services and eliminates several problems of confinement production. If animals consume plants growing in a field, their waste is deposited and recycled in the field, which increases plant growth [8]. This system also takes advantage of the high efficiency of ruminant guts for converting low-quality forage into high-protein human foods, including dairy products. When appropriately stocked and managed, grassland-ruminant ecosystems are efficient and sustainable methods of producing high-quality protein with minimal environmental impacts [8]. Figure 1 illustrates the transition scheme from current farming systems to maximize the production and profits using the rice forage system as a community-based production method, where the trade in feed and manure enhance local sustainability.

Figure 1. Transition from the farming systems to build the maximize production and profits (above) to community based production systems by feed and manure trade that enhance local sustainability (below).



Senda [9] showed that rice-based beef cattle production has several economic and environmental benefits in mountainous regions. However, little information is available on rice-based dairy farming systems in major rice production areas. Planting forage for the winter season can increase the utilization of land use ratio for paddy fields. According to field experiments conducted by Komatsuzaki *et al.* [10], Italian ryegrass (IR; *Lolium multiflorum*) and hairy vetch (HV; *Vicia villosa*) produced more biomass and reduced nitrogen leaching in the winter season, plants such as these can be used as feed for dairy cattle. IR is known to have a high energy content and good profitability. HV is a winter-hardy, leguminous green manure crop that is increasingly used in several countries [5,11–14]. HV can be used as winter forage, but it also suppresses weeds and supplies nitrogen to the following summer crop when used as green manure or mulch because of its rapid nitrogen mineralization [13]. The selection of forage species is another issue when adopting rice forage system. In general, leguminous green manure species are planted in Japan for nutrient management [15]. HV is a popular species, which provides a green manure in rice production, although this species often causes toxicosis in grazing cattle [16]. The toxicosis caused by HV was reduced after processing into hay because drying reduces *cyanamide* contamination of HV [17]. IR is also a common winter annual grass forage in Japan, which has good productivity in upland field conditions [18,19], and it is also used as a cover crop in rice paddy fields [6]. However, little information is available on IR productivity in paddy fields after rice harvest or in mixed culture with HV.

Various farming systems such as conventional tillage (CT) and no-tillage (NT) practices can also be used. These two farming systems have been tested to determine the impacts of CT and NT. The NT practice has been adopted worldwide in the past few decades, as it reduces the negative effects of soil erosion that occur with CT. NT is an alternative that reduces costs and the amount of field work required, compared with those of CT. NT also reduces the risk of erosion and improves the physical and chemical properties of soil [20]. The NT system has recently emerged in Japan, although farmers were hesitant about adopting NT because of the high weed pressure during summer. However, the use of NT for winter crop and forage production provides cost savings. NT allows the farmer to save significant amounts of time required for seedbed preparation before planting, which can result in more timely planting and an increased acreage using the same equipment and labor force. Therefore, NT may reduce forage production costs and labor requirements.

In the present study, we evaluated the profitability of rice forage systems in a major paddy production area of Kanto, Japan, using field experiments and on farm evaluation of farmers. The main objective of this study was to analyze the utilization of paddy fields during the winter season for cultivating forage, and evaluating the forage cost, productivity, and self-sufficient feed ratio in a rice-based dairy farming system.

2. Materials and Methods

2.1. Experimental Design

This study was conducted in the Field Science Center for Research and Education, College of Agriculture, Ibaraki University. The study site was located at latitude 360°1′48.31″N, longitude 140°012′40.26″. The experimental field was established in April 2012, as a long-term paddy rice research experimental site, on volcanic ash soils in the Kanto region of Japan. The soil was a typical Andisol with a sandy loam texture in the upper surface, with a gradual increase in clay with depth. The study began in the early winter season of October 2012, and continued until April 2013. The field experiment investigated various factors to determine the best forage growing conditions. The climate varied during the study, the highest temperature was 17.1 °C, with the average being 3.4 °C. The highest precipitation was 139.5 mm with the average being 63.28 mm (Table 1) [21].

Table 1. The average of climate conditions in experimental season (October–May) and normal average in field experimental research.

	2012–2013 season		**30 years average**	
Month	Air Temperature (°C)	Precipitation (mm)	Air Temperature (°C)	Precipitation (mm)
October	17.1	32	16.8	151.5
November	9.9	61	11.1	74.4
January	4.5	60.5	6.1	43.3
February	3.4	44	3.7	43.5
March	9.4	39	4.4	50.1
April	12.2	67	7.6	93.2
May	16.4	139.5	12.9	101.1

The data were subjected to statistical analyses using ANOVA (Statview, SAS Institute) with a split-split-plot design and Fisher’s exact test, where $p < 0.05$.

The rice was harvested on 15 September 2012. As 10 Mg ha^{-1} cow manure (C: 21.7%, N: 2.2%, C/N: 9.7) were applied before rice planting to the paddy fields. Chemical fertilizer was applied at N: 60 kg ha^{-1}, P_2O_5: 60 kg ha^{-1}, and K_2O: 60 kg ha^{-1}) at the rice planting time. Forage cultivation was started on 22 October 2012. The forage types used in this study were IR, HV, mixed seeding (IR + HV), and fallow (native weeds, NW). The seeding rate was 50 kg ha^{-1} for IR and HV, with 25 kg ha^{-1} each of IR and HV for the mixed seeding treatment. The study used a randomized complete block design with split plots and four replicates, where the unit plot size was 2 × 6 m. The main plot factor was the tillage system: CT (rotary tiller) and NT. The subplot factors were the forage species: IR, HV, IR + HV, and NW. In total, 32 plots were designed in this study.

2.2. Sampling and Chemical Analysis

Field data were collected at four different harvest times. The forage was harvested during the winter season until the early spring (third week in December, first week in March, fourth week in March, and second week in April). After the crop was harvested, the fresh weight was measured before drying at 65 °C for 72 h and weighed again. The plant biomass was converted into Mg ha^{-1} on a dry weight (DW) basis. The leaves and stems were ground before the following analyses: moisture content (MC), crude ash (CA), organic material (OM), crude protein (CP), extract ether (EE), crude fiber (CF), and nitrogen-free extract (NFE), were determined according to the official analytical methods of the Association of Official Analytical Chemists [22]. Nitrate analysis was performed using an SPCA ultraviolet absorption spectrophotometry system [23].

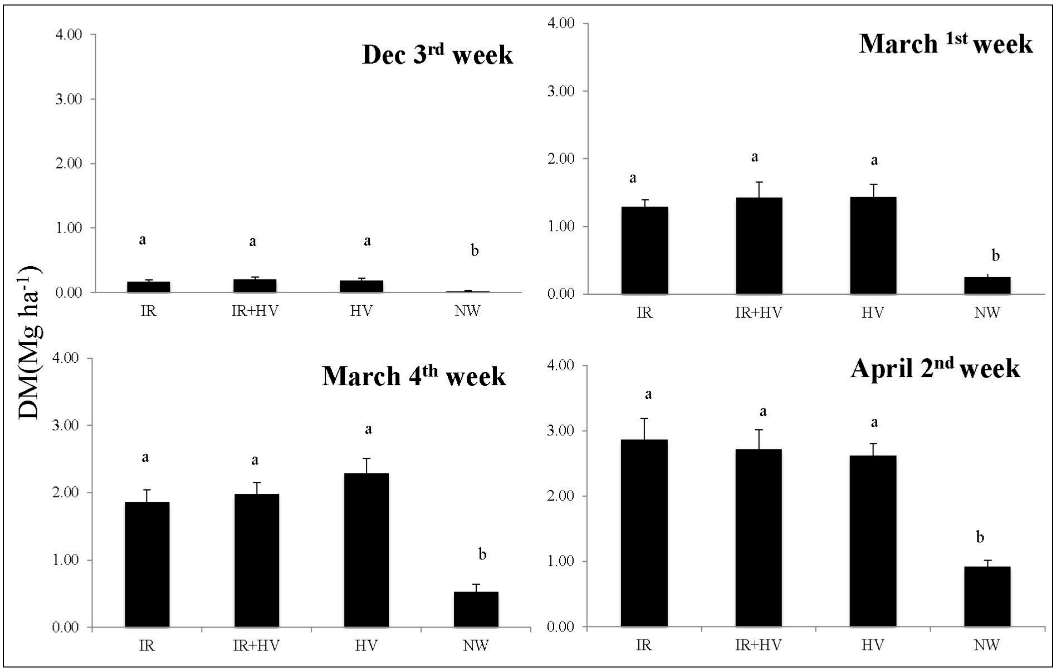
2.3. Statistical Analyses

The data were subjected to statistical analyses using ANOVA (Statview, SAS Institute) with a split-split-plot design and Fisher's exact test, where $p < 0.05$.

3. Results and Discussion

The forage productivity after the rice harvest greatly varied, depending on the harvest timing and their species but not the tillage systems. The dry matter (DM) production by each species also differed significantly, depending on the harvest time ($p < 0.05$) (Figure 2). The tillage practices did not have significant effects on DM production after the March harvest, although there was a significant difference at the time of the first harvest. DM production was 1.29 Mg ha^{-1} for IR, 1.43 Mg ha^{-1} for IR + HV, and 1.43 Mg ha^{-1} for HV. Later in March, DM production increased by 44.2% for IR, 38.4% for IR + HV, and 59.8% for HV. At the peak harvest time, DM production increased to 2.86 Mg ha^{-1} for IR, 2.71 Mg ha^{-1} for HV + IR, and 2.61 Mg ha^{-1} for HV.

Figure 2. The measurement dry matter (DM) production for several cover crops species on paddy field during winter season.



Abbreviations: IR (Italian Rye grass), IR + HV (Italian Rye Grass + Hairy Vetch), HV (Hairy Vetch), and NW (Native Weed). Vertical bar shows the standard error. The subscript letter describes significance different test by Least Square Determination (LSD) in $p < 0.05$.

In addition, the forage species and harvest timing also significantly affected the nutrient content (Table 2). Different forage species had significantly different CA contents ($p < 0.05$) among all harvest times. HV had the highest mineral percentage (13.7%), followed by NW (10.7%), IR + HV (9.5%), and IR (6.3%), in the fourth week of March. The amount of OM was significantly different among all harvest times ($p < 0.05$). The percentage OM slowly decreased until the last harvest time. The amount of OM was highest in IR, compared with that in IR + HV and HV. Each forage species had significantly different CP percentages in the first week of March and the second week of April ($p < 0.05$). On average, HV had the highest CP content (23.4%), followed by IR + HV (17.4%), NW (14.9%), and IR (10.5%). The highest EE percentage was of HV (3.6%), followed by IR + HV (2.9%), NW (2.5%), and IR (2.2%). The CF percentage also increased with the harvest time and the highest CF percentage occurred at the final harvest time. On average, the CF content was highest with IR + HV (16.0%), followed by HV (15.3%), NW (15.1%), and IR (15.1%). The forage species also had a significant effect on the NFE concentration ($p < 0.05$). The highest NFE concentration was observed with IR (65.1%), followed by IR + HV (55.4%), NW (55.3%), and HV (41.1%) in the first week of March.

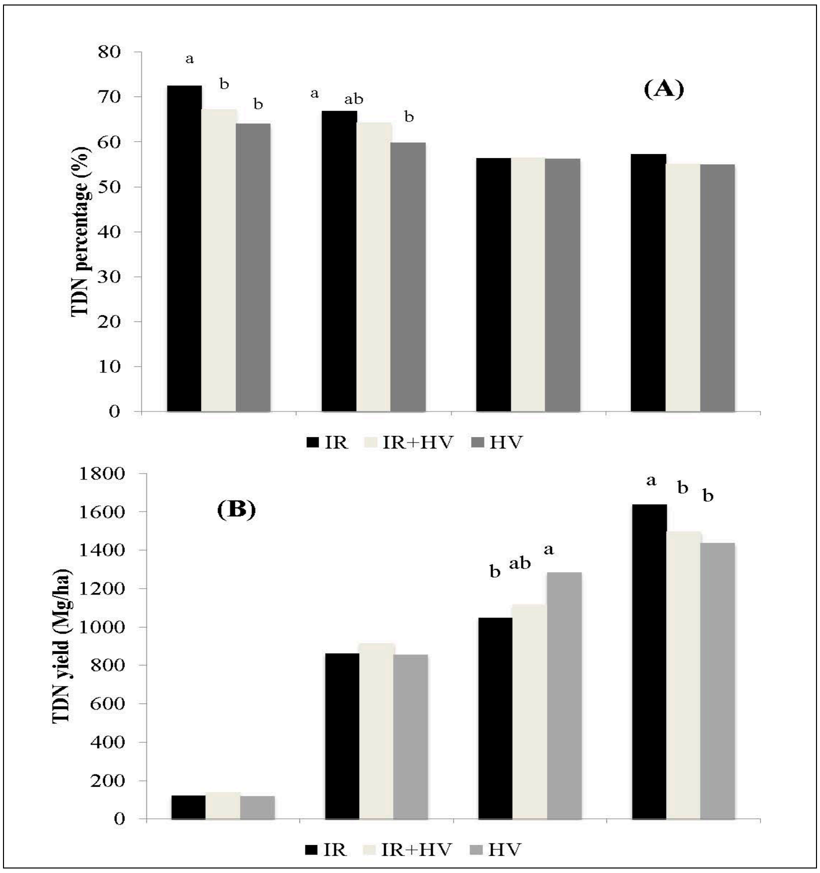
Table 2. The Nutrients quality percentage (%) of several forage species cultivated in paddy field during winter season.

Forage	**December: Third week**							**March: First week**						
	CA	OM	CP	EE	CF	NFE	NO_3–N	CA	OM	CP	EE	CF	NFE	NO_3–N
IR	5.7 ^{ab}	93.2	15.5	2.0 ^{c}	5	68.9 ^{b}	780	6.8 ^{b}	93.7 ^{a}	10.9 ^{b}	2.3 ^{b}	10.4	65.1 $^{a/}$	609.2
IR + HV	6.6 ^{a}	92	19.8	2.8 ^{ab}	6.1	59.9 ^{b}	1049.9	8.0 ^{ab}	90.2 ^{ab}	17.9 ^{ab}	3.2 ^{a}	10.7	55.4 ^{ab}	607.6
HV	6.7 ^{a}	88.7	22.6	3.5 ^{a}	6.4	57.3 ^{b}	1435.6	11.3 ^{a}	86.3 ^{b}	25.9 ^{a}	3.5 ^{a}	12.6	41.1 ^{b}	1199.7
NW	6.3 ^{a}	88.1	16.4	2.1 ^{cb}	ND	70.4 ^{a}	-	11.9 ^{a}	89.3 ^{ab}	16.8 ^{b}	2.5 ^{ab}	8.5	55.3 ^{ab}	634.2
ANOVA	**	ns	ns	**	ns	**	ns	**	**	**	**	ns	**	ns
Forage	**March: Fourth week**							**April: Second week**						
	CA	OM	CP	EE	CF	NFE	NO_3–N	CA	OM	CP	EE	CF	NFE	NO_3–X
IR	6.3 ^{c}	94.4 ^{a}	8.8 ^{b}	2.5 ^{b}	20	56.4 ^{a}	599.9	6.8 ^{a}	93.2 ^{a}	6.6 ^{b}	2.2 ^{b}	25.0 ^{a}	54.2 ^{ab}	241.4 ^{b}
IR + HV	9.5 ^{bc}	91.7 ^{ab}	17.2 ^{ab}	2.8 ^{b}	21.6	42.2 ^{ab}	656.9	8.0 ^{ab}	92.0 ^{a}	14.6 ^{ab}	2.9 ^{ab}	25.5 ^{a}	42.6 ^{b}	507.8 ^{ab}
HV	13.7 ^{a}	90.7 ^{b}	23.4 ^{a}	3.9 ^{a}	19.9	33.2 ^{b}	818.1	11.3 ^{b}	88.7 ^{ab}	21.6 ^{a}	3.6 ^{a}	22.1 ^{a}	36.1 ^{b}	807.6 ^{a}
N NW	10.7 ^{b}	92.3 ^{ab}	15.4 ^{b}	2.9 ^{b}	19.2	45.7 ^{ab}	585	11.9 ^{b}	88.1 ^{b}	10.9 ^{b}	2.6 ^{ab}	17.8 ^{b}	54.5 ^{a}	493.8 ^{b}
ANOVA	**	**	**	**	ns	**	ns	**	**	**	**	**	**	ns

Abbreviations: IR (Italian Rye Grass); HV (Hairy Vetch); NW (Native Weed); CA (Crude Ash); OM (Organic Material); CP (Crude Protein); EE (Extract Ether); CF (Crude Fiber); NFE (Nitrogen Free Extract); ND (not Detected); "-" (not measured);** indicated significant at $p < 0.05$; ns (not significant); Subscripts with the same letter in the same column showed the significant different test by Least Square Determination (LSD) in $p < 0.05$.

The TDN (Total Digestible Nutrients) yields of the forages showed that the tillage treatment had no significant effect on the TDN percentage and its accumulation (Figure 3). However, the forage species had a significant effect on the TDN percentage and its accumulation at the second to last harvest time ($p < 0.05$). The TDN percentage slowly decreased with the growth period. The highest TDN percentage occurred with IR (63.9%) and followings were 61.4% in IR + HV, 58.9% in HV, and 44.5% in NW. The TDN yield was also highest with IR (1638 kg ha^{-1}), followed by IR + HV (1496 kg ha^{-1}), and HV (1440 kg ha^{-1}), in the second week of April. The results obtained in a paddy field were comparable to the forage productivities in pasture and upland conditions [24], although the DM production was somewhat lower compared with other studies [16]. These results suggest that the forage production in the first week of March will be adequate to start grazing in paddy fields of IR because they produce highest DM production. In addition, we also recommend that HV and IR + HV be used for silage because their productivities were comparable to IR.

Figure 3. The calculation of TDN Percentage (%) of several forage crop in paddy field during winter season (**A**) and TDN yield (**B**).



The subscript letter shows significance different test by Least Square Determination (LSD) in $p < 0.05$. The data of NW was not measured since there was not enough of a sample in the third week of December.

The results also demonstrated that there were no differences in the forage production and nutrition contents with CT and NT. NT farming practice have several advantages with regard to labor saving, and we confirmed that the most suitable time to plant forage seeds in paddy fields after the rice harvest is during the autumn rainy season, when farmers generally hesitate to plant seeds because of the muddy soil conditions, particularly in low land paddy.

4. Application of Technology

4.1. On-Farm Evaluation and Cost Analysis of Rice Forage Systems

The forage production costs were evaluated on the basis of the farmer's evaluation that was Ueno dairy farm who planned to graze in the early spring was located in Inashiki city, Ibaraki Prefecture, Japan, and a rice grower who collaborated with the same dairy farmer, were evaluated their views on adoption of the rice-based forage system (Table 3). This dairy farmer is unique because he tries to involve local feed in his farming, which is completely different from most dairy farmers in Japan, who are over depending on imported feed. The grassland area, scale of dairy cattle and milk production, and feeding schedules were evaluated using a questionnaire. For the rice grower, the farming scale, rice production, and facilities were also evaluated using a questionnaire. The Ueno dairy farm and the rice grower already had a strong relationship because they traded rice straw; therefore, they were willing to adopt the rice forage production system. The rice grower supplied grazing land in the winter season and received manure in return from the dairy farmer. Based on the facilities, and the scale of production, the annual fixed costs, variable costs, and materials costs were evaluated on a commercial basis. We also calculated the cost of forage production, according to the rice grower's farming scale and forage productivities determined in our experiment.

Table 3. The outline of dairy farms and paddy rice grower.

Resources	Size of farm and facilities
Dairy cattle structure	32 dairy cattle, 6 heifers, 3 calves
Milk production	20 kg/day; 6000 kg milk annually
Milk Products	Fresh milk and Ice Cream
Grass land	5 ha
Grazing land	5 ha
Labor	1 for full time
Facilities	Tractor 60kw (1 unit), 58kw (1 unit), 55kw (1 unit) and 29kw (2 units), Mower Conditioners, Hay Tedder, Role baler, Roll Grove and Lapping lap, Forklift, Manure spread, Rotary machine, plowing machine, and lime shower.
Paddy land	5 ha
Rice production	25 t
Labor	1 for full time; 1 for part time

SSR was used to compare the current situation with that of after adopting the rice forage system, according to the dairy farmer's feeding schedule. To determine the modified feeding schedule, the use of self-produced hay was the main feed from December to February, and paddy grazing started in March.

SSR for dairy farming was also determined on the basis of the feeding data provided by the farmer, which was according to current feeding practices. Using field experimental data related to the forage productivity, nutrient quality, and the scale of rice farming, an improved feeding schedule was determined so that the same amount of total digestible nutrients (TDN) was supplied to the dairy farmer after adopting the rice forage system. The feed nutrient contents were evaluated according to the Japanese feed nutrient standards provided by the National Agriculture and Food Research Organization (2009) [24].SSR was calculated as follows:

$$\text{SSR} = \frac{\sum_{J=1}^{m} TDNj \times FRj}{\sum_{i=1}^{n} TDNi \times FRi}$$

where

m = amount of feed produced by the farmer (self-production)
n = amount of commercial and self-produced feed
i = amount of feed provided by the farmer
j = amount of commercial and self-produced feeds provided by the farmer
$TDNi$ = TDN (%) of feed produced by the farmer
$TDNj$ = TDN (%) of commercial and self-produced feeds
FRi = feeding rate (kg/cattle) using feed produced by the farmer
FRj = feeding rate (kg/cattle) using commercial and self-produced feeds

4.2. Cost Analysis of Rice Forage System and Possibility of SSR Improvement

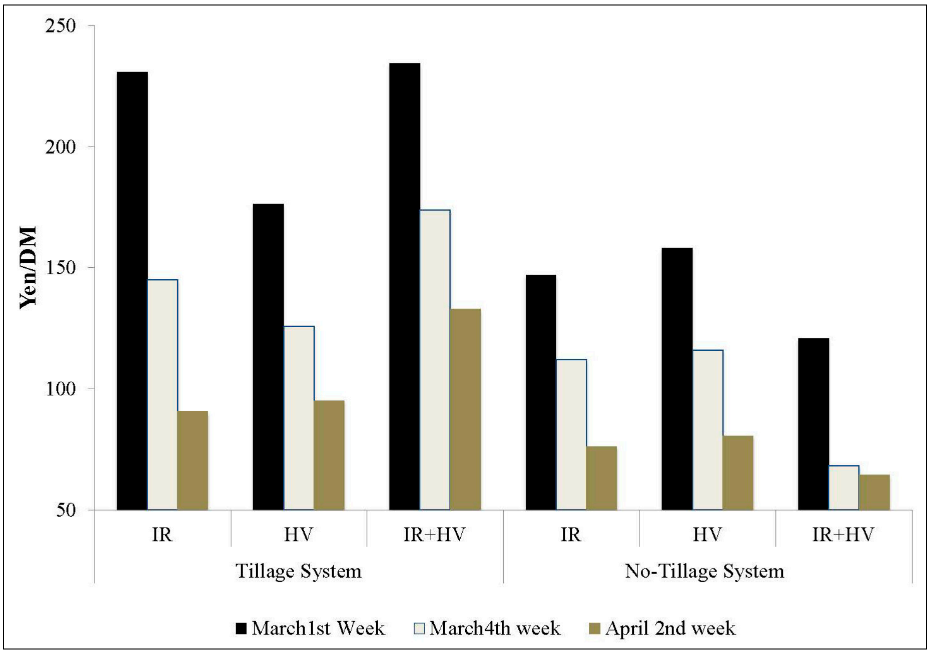
The cost comparisons of forage production using CT and NT indicated that there were significant reductions in costs when using NT compared with CT (Table 4). The working hours required for soil preparation and forage seeding were 49% lower when using NT compared with those using CT. The NT system also eliminated the fixed costs of using a rotary tiller. Thus, the fixed costs with NT were 33% less than with CT. Other costs were also reduced with NT, such as variable and labor costs. The total cost of forage production was 33% lower with NT than with CT.

Table 4. Comparisons of total costs, total fixed costs, and total variable costs using conventional tillage (CT) and no-tillage (NT) in paddy fields during the winter season.

Tillage System	Working hours	Fixed Costs	Variable costs	Material costs	Labor costs	Total
	hr ha^{-1}	yen ha^{-1}	yen ha^{-1}	yen ha^{-1}	yen ha^{-1}	yen ha^{-1}
CT	26.5	165,282	26,500	45,000	39,750	276,432
NT	12.3	127,293	12,300	45,000	18,450	203,043

The forage production cost per DM was also lower with NT than CT, although the growth period greatly affected the production cost. In the third week of December, the average cost for IR was 1843 Yen DM kg^{-1} production. The average cost with NT production was 28.1% lower compared with the CT system (Figure 4). The results showed that the cost of paddy forage production in March were comparable with imported hay, particularly using the NT system.

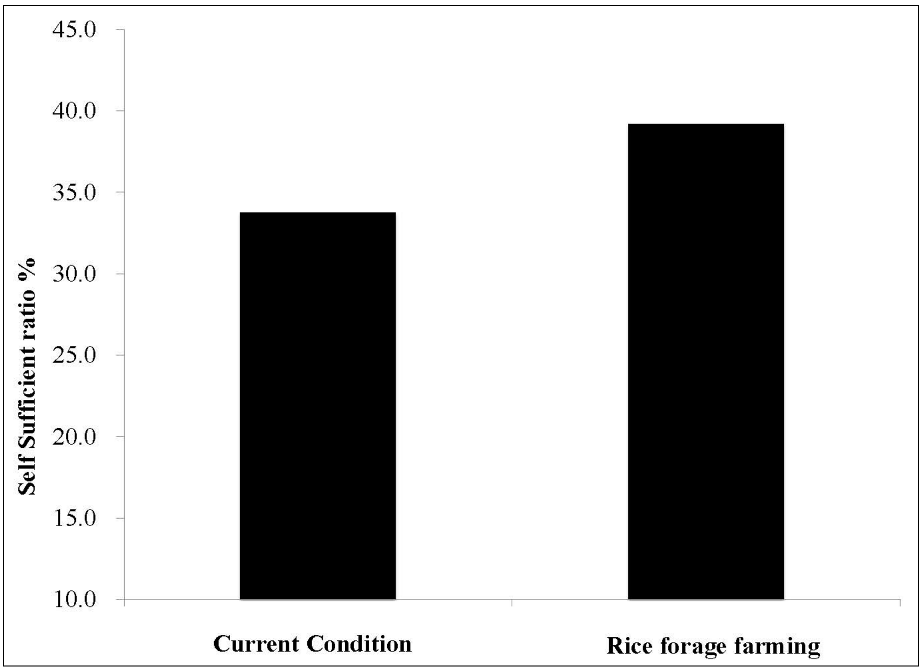
Figure 4. Average production cost per 1 kg dry matter (DM) production (Yen/DM) for several crops grown in paddy fields during the winter season.



IR: Italian rye grass; IR + HV: Italian rye grass and hairy vetch; HV: hairy vetch, and NW: native weeds.

The changes in the feed mechanism strategy after adopt rice forage system improved SSR (Figure 5). In the current condition, the average SSR was 33.8%, whereas it may improve to 39.2%. Thus, the utilization of grazing with NT system could improve the SSR by 5.4%. This information may be used to improve SSR to facilitate sustainable dairy farming in Japan.

Figure 5. Average self-sufficient ratio (SSR) in the current condition and after adopting the rice forage farming system.



4.3. Benefits of the Rice Forage System in Japan for Sustainability

Factory-farmed livestock production is widespread in Ibaraki, which is a major agricultural area for rice and animal production. However, this system causes considerable nutrient pollution to Lake Kasumigaura, Ibaraki, Japan, as excessive amounts of manure pile-up on farms [25]. Most factory livestock are reared on imported feed because of the limited amount of available grassland. The application of the excess manure to small grassland would lead to considerable nutrient leaching and nitrate concentration in the forage, thereby reducing its quality [26]. The increased cost of imported hay implies that the scale of intensive factory livestock production is increasing to obtain economies of scale.

This area also has major paddy rice production areas, where conventional farming is primarily based on chemical fertilizers. Paddy rice production improves the nitrate concentration in water because of its uptake by the rice plants, while denitrification occurs during the flooding paddy season [20]. However, nitrate leaching from paddy fields occurs in the wet season because of nitrifying soil conditions, particularly during winter fallow management [6].

The rice forage system has several benefits for dairy farming and rice production from an agro-ecological perspective. This system increases the crop diversity in paddy fields and maintains soil coverage, as well as facilitates nutrient cycling between the paddy field and dairy cattle. There are other agricultural benefits such as maintaining the soil organic matter protection from soil erosion, reduction of weed pressure (because of the cover with winter forage), and better retention of soil nutrients. Our results showed that the NT farming system is comparable with imported hay and that it improved the SSR for dairy farming feed. The limitation existing in evaluation is that only one dairy farmer was evaluated. However, this data will be valuable when reconstructing Japanese dairy farming to improve the self-sufficient ratio for feed is considered.

In the future, we will investigate further methods to provide additional benefits to both sectors. Cultivation of the forage crop can begin in the winter; therefore, grazing can be conducted in the spring. The rice grower does not use the paddy field during the winter season, so this resource can be utilized for dairy farming to enhance biomass production and increase SSR. This system allows dairy farmers to ensure that their cattle engage in grazing activities. This collaboration has several benefits: (1) increasing SSR because of the additional biomass from the forage crop; (2) grazing activity for cattle; (3) reduced use of chemical fertilizer because of the additional nutrients from dairy cattle manure in the paddy field; and (4) and the potential for organic rice production. Rice forage crop production has positive impacts on the environment because it prevents nitrate leaching, while it also facilitates landscape management.

5. Conclusions

The utilization of paddy fields during the winter season could increase the SSR for dairy farming in Japan. Field experiment results suggested that forage production in the first week of March will be suitable for the start of grazing in paddy fields with IR, which had the highest TDN yield in the second week of April.

Self-produced hay often has higher costs than imported hay. However, our study showed that it is possible to reduce the cost of self-produced hay by using a NT system after the rice harvest, followed by spring grazing management. The NT system provided several savings compared with the CT system, including lower total fixed costs and total variable costs for forage production. The average cost with NT production was 28.1% lower compared with CT production. A comparison of the current condition and that after adopting the rice forage system showed that the SSR may improve from 33.8% in the current condition to 39.2% with the new system. Thus, the utilization of the rice paddy grazing system with NT could improve the SSR by 5.4%.

The rice forage system has several benefits for dairy farming and rice production from the perspective of sustainability. This study also showed that the rice forage system has economic benefits when adopting NT forage production and paddy field grazing.

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Author Contributions

The individual contribution and responsibilities of the authors were as follows: Windi Al Zahra: field experiment and on dairy farm evaluation, sample analysis, data analysis and article writing. Takeshi Yasue: research idea and design. Naomi Asagi: research idea and design. Yuji Miyaguchi: research idea and design. Bagus Priyo Purwanto: research idea and design. Masakazu Komatsuzaki: research idea and design, grant holder of research financing, participation in research circle with municipal staff and supervision of data collection and analysis, and article writing.

Conflicts of Interest

The authors declare no conflict of interest.

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