Achieving a Nitrogen Balance for Japanese Domestic Livestock Waste: Testing the Scenario of Planting Feed Grain in Land Left Fallow

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ABSTRACT : In this study, we assess the recent changes in the amount of excretion by the livestock industry, and discuss the effects of increasing the ratio of cultivated land on the reduction of surplus nitrogen from a cost-performance perspective. Nitrogen has contributed to acidification of ecosystems and nitrate concentrations in groundwater, especially in Europe. Therefore, we assessed the level of nitrogen waste from the domestic Japanese livestock industry, including cattle, swine and poultry during the period 1987-2001. This assessment assumed that 40% of the nitrogen from the domestic livestock industry was emitted as gas into the air and that 60% of the nitrogen was contained in manure used on domestic cultivated land. Nitrogen excreted from livestock, excluding gas emission, decreased by 11% from 0.504 million tons to 0.447 million tons during 1993-2001. Thus, the peak period of nitrogen excretion from livestock is already past in Japan. However, the area of cultivated land under management also decreased during 1990-2000. In addition, the area of paddy and upland fields left unplanted for a year increased during 1990-2000. Therefore, if all manure from the domestic livestock industry had been utilized on the fields as organic fertilizer, but not on arable land left uncultivated for the past year, the nitrogen per net area of cultivated land would have increased by 5%, from 125 to 131 N kg/ha, during 1990-2000. To reduce the nitrogen ratio on cultivated land through the planting of feed grain to utilize the nitrogen, a comparison of the cost performance of feed grains indicated that barley would be more suitable than wheat, rice or soybean. Had barley been planted in 100% of the land left fallow for the past year in 2000, 4% (20,000 tons) of the nitrogen from livestock waste would have been used in the harvest, and the nitrogen per land unit would have not increased but decreased from 125 to 121 N kg/ha during the same decade. Furthermore, when converted into Total Digestible Nutrients, 7% of imported feed corn could have been replaced with the harvested barley in 2000. Planting barley on this fallow land had three benefits; reducing the risk of manure overload on the land, slowing down the decrease in cultivated land, and raising the feed self-sufficiency ratio. Thus, it would be beneficial to plant feed grain such as barley in land left fallow for the past year through utilization of manure. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 7 : 1026-1032)***

Key Words : Nitrogen Balance, Livestock, Barley, Manure Overload, Groundwater, Land Left Fallow for Past Year

INTRODUCTION

A new Japanese agricultural law (The Basic Law on Food, Agriculture and Rural Areas) was enacted in 1999. This law consists of new general provisions and basic policies. In the general provisions, Article 2 refers to securing a stable food supply and Article 4 mentions sustainable agricultural development. To put these general provisions into practice, Article 15 provides basic policy targets in order to improve the self-sufficiency ratio, and Article 32 establishes the policy of maintenance and promotion of the natural cyclical function of agriculture. If the Japanese government fully implemented Article 15, the number of Japanese domestic livestock animals would increase. As the number of livestock animals increases, an increase in the amount of waste from livestock could naturally be expected. If the Japanese government implemented both Articles 15 and 32 at the same time, it would be possible to compost the increased waste and utilize the composted manure on cultivated land as fertilizer. The composted manure would need to compete against other fertilizers, such as chemical and organic fertilizers, crop residues, and food waste. If composted manure won a share of the competitive fertilizer market, and the loaded amount of other nitrogen fertilizers utilized did not decrease, there would be an increased risk of overload of nitrogen from livestock waste, which could pollute groundwater in the future, something the Japanese domestic livestock industry should avoid.

Bouwman et al. (1997) reported that ammonia (NH_3), especially nitrogen leaching, has been the main cause of acidification of ecosystems in Europe, the Indian subcontinent, and China, reflecting the patterns of animal densities. Misselbrook et al. (2000) reported that the estimation of nitrogen emissions is a critical requirement for nitrogen budgets, especially in Europe. The main cause of the increased nitrate concentrations in groundwater is the fact that the inputs of fertilizers and animal manure to agricultural land have increased much more than the nitrogen increment used in the harvested products. Specifically, the rapid intensification of livestock production has contributed to a great increase in nitrogen surpluses of agricultural land in the Netherlands (Oenema et al., 1998). The Dutch government has introduced

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Table 1. Nitrogen amount from waste from Japanese domestic livestock assessed by 10 different livestock classifications (tons)

Year	Dairy cattle			Beef cattle			Pig		Poultry		Total α
	2 years old and over milking cow	2 years old and over undelivered & delivered cow not milkig at present	Less than 2 years old	Less than 2 years old	2 years old years over	Dairy cattle for beef	Less than 6 months old	6 months old and over	Layer	Broiler	
1987	117,194	12,865	36,586	39,323	42,525	52,429	111,923	44,453	224,967	148,262	830,526
1988	116,302	12,091	36,412	38,991	42,206	53,356	115,305	46,314	227,949	148,197	837,124
1989	118,867	11,670	36,644	39,276	42,579	52,738	116,878	46,593	228,205	147,129	840,578
1990	120,540	-	-	-	-	53,459	116,554	46,165	224,370	143,871	-
1991	120,651	11,670	37,859	41,644	45,456	55,261	-	-	224,560	136,492	-
1992	120,540	11,845	38,438	35,539	47,801	55,776	-	-	234,824	132,571	-
1993	120,874	11,670	37,744	44,961	47,322	56,034	-	-	237,576	129,455	-
1994	117,306	11,670	36,817	45,671	48,707	56,240	-	-	235,080	121,827	-
1995	115,299	10,826	35,312	-	-	56,291	-	-	232,082	114,452	-
1996	115,410	10,510	34,328	44,108	47,641	55,467	-	-	228,227	112,961	-
1997	114,964	10,123	33,402	42,829	46,682	55,210	-	-	231,104	108,510	-
1998	113,961	9,807	32,360	41,929	45,563	57,064	103,209	30,454	229,100	106,780	770,225
1999	112,400	9,526	31,086	41,076	44,977	58,248	103,085	30,175	226,142	102,666	759,380
2000	110,615	9,104	29,697	-	-	57,888	102,473	29,728	224,334	103,672	-
2001	108,274	8,787	29,234	41,360	42,898	57,991	102,498	29,300	222,830	101,665	744,838

environmental policies to decrease the use of N-fertilizer since 1998 (Berentsen et al., 2003.)

In Japan, the government bears responsibility for assessing the risk of overload of manure after enforcement of the new agriculture law and for adoption of new plans to help the Japanese domestic livestock industry avoid nitrogen overload (Ogino et al., 2003).

Research on several practices that could reduce nitrogen in the system target three scenarios, such as decreasing the number of livestock, replacing chemical fertilizer with manure, and increasing the area of cultivated land where manure could be utilized.

Hojito et al. (2003) tested four scenarios for nitrogen abatement strategies as follows. The first scenario proposed a reduction of 30% in chemical fertilizer. The second scenario proposed discharging the nitrogen in the manure treated by sewage treatment, while the third scenario proposed utilizing all of the fallow fields to obtain decreased nitrogen concentrations by cropping. The fourth scenario proposed a combination of the above scenarios. Ikeguchi et al. (2002) reported that decreasing the number of livestock would bring about a reduction of nitrogen excreted from livestock in Japan. Mishima (2001) recommended that decreasing the input of chemical fertilizer could be effective in reducing the environmental risk of surplus nitrogen. However, farmers are the end users of chemical fertilizers, and it is difficult to decrease the input of chemical fertilizers as long as they are so easy to use. Another strategy to mitigate surplus nitrogen used on cultivated land is to increase its area. As the area of cultivated land increases, the ratio of nitrogen to cultivated land would thus decrease. Furthermore, as Ozeki (2001) pointed out, almost no research has been published on this issue from the standpoint of cost performance in Japan.

In this study, therefore, we assess the recent changes in the amount of nitrogen excreted by the livestock industry on our empirical model with statistical data published by the Ministry of Agriculture, Forestry and Fisheries (MAFF), and then discuss the effects of increasing the ratio of cultivated land on the reduction of surplus nitrogen from a cost-performance perspective.

MATERIALS AND METHODS

Assessment of nitrogen from Japanese domestic livestock wastes

The method of calculating the amount of nitrogen (N) from livestock wastes developed by Tsuiki and Harada (1997) was used to assess the amount of N produced by the Japanese livestock industry. This method is a computer program for estimating the amount of livestock wastes based on the Japanese feeding standard for livestock. Dairy cattle, beef cattle, pig, layer and broiler poultry were considered in this study. This calculation system uses the number of livestock of 10 different types for each year. Subdivided livestock types include two kinds of dairy cattle, three kinds of beef cattle, and two kinds of pig. The total number of livestock thus subdivided by type was obtained from the 76th Statistical Yearbook published by MAFF (2002). See Table 1.

Table 1 shows the nitrogen tonnage from Japanese domestic livestock for each year during the period 1987-2001. The total nitrogen tonnage is only available for 6 out of the 15 years; data for the other 9 years are unavailable. The Tsuiki and Harada method requires the number of animals for each of the 10 subdivided livestock types as fundamental data to calculate the total tonnage. The complete data on the number of domestic livestock

Table 2. Nitrogen amount from Japanese domestic livestock industry waste and nitrogen amount to livestock industry waste excluding gas emission (tons)

Year	Dairy cattle	Beef cattle	Pigs	Layers	Broilers	Total β	α	α÷β	β×0.95	Nitrogen excluding gas emission β×0.95×0.6
1987	228,479	136,221	141,732	224,967	148,262	879,661	830,526	0.944	835,678	501,407
1988	224,911	136,479	146,363	227,949	148,197	883,899	837,124	0.947	839,704	503,822
1989	226,472	136,530	148,123	228,205	147,129	886,460	840,578	0.948	842,137	505,282
1990	229,482	139,157	147,499	224,370	143,871	884,379	-	-	840,160	504,096
1991	230,486	143,998	141,495	224,560	136,492	877,031	-	-	833,179	499,908
1992	232,159	149,251	136,889	234,824	132,571	885,693	-	-	841,408	504,845
1993	230,598	152,238	134,604	237,576	129,455	884,471	-	-	840,248	504,149
1994	225,134	153,011	132,594	235,080	121,827	867,646	-	-	824,263	494,558
1995	217,551	152,702	127,951	232,082	114,452	844,738	-	-	802,501	481,501
1996	214,875	149,406	123,582	228,227	112,961	829,051	-	-	787,598	472,559
1997	211,530	146,882	122,446	231,104	108,510	820,472	-	-	779,448	467,669
1998	207,404	146,676	123,632	229,100	106,780	813,591	770,225	0.947	772,912	463,747
1999	202,498	146,367	123,320	226,142	102,666	800,992	759,380	0.948	760,943	456,566
2000	196,699	145,389	122,408	224,334	103,672	792,502	-	-	752,877	451,726
2001	192,462	144,410	122,146	222,830	101,665	783,514	744,838	0.951	744,338	446,603

Table 3. Nitrogen concentration changes during the period 1990-2000

Year	Total area of cultivated land under management γ (ha)	Unplanted paddy and upland fields (excluding permanent crops left fallow for one year			γ-δ (ha)	Nitrogen from Japanese domestic livestock industry ε (N ton)	Nitrogen concentration ε/(γ-δ) N kg/ha
		Unplanted paddy field (ha)	Upland field (ha)	Subtotal δ (ha)			
1990	4,198,732	92,198	59,952	152,150	4,046,582	504,096	124.6
1995	3,970,051	77,207	79,279	156,486	3,813,565	481,501	126.3
2000	3,734,288	205,410	72,487	277,897	3,456,391	451,726	130.7

subdivided by type were not published by the Japanese government for the missing 9 years. Therefore, the Tsuiki and Harada method could not assess the amount of livestock wastes and nitrogen from the Japanese domestic livestock industry for those 9 years.

The 60% of nitrogen from the domestic livestock industry was assumed to be entirely applied to domestic cultivated land as manure in this study based on the report by Ikeguchi et al. (2003) and Hojito et al. (2003) that 40% of nitrogen from Japanese domestic livestock was emitted as gas into the air. Table 2 shows nitrogen from Japanese domestic livestock for each year during the period 1987-2001. The nitrogen from domestic livestock for each year in this table was calculated based on 5 livestock types and includes the total number of livestock of each type. Data on these five livestock types have been consistently published by the Japanese government. Comparing the N amounts in Table 1 and 2, the N amounts in Table 2 multiplied by 0.95 were used as the nitrogen excreted from livestock. The nitrogen indicated in Table 2 for each year was adjusted by the N amounts in Table 1.

Estimation of N concentration on farmland from livestock wastes

This report assumes that N from livestock wastes was entirely applied to farmland, and the calculated N concentration is shown in Table 3. This table shows N changes during the period 1990-2000 on the total area of cultivated-land under management, the area excluding unplanted fields for one year and the N from Japanese domestic livestock industry based on the condition that 40% of the livestock waste was emitted into the air as gas. Detailed data on farmland areas are published every 5 years. The farmland data were obtained from the 76th Statistical Yearbook of MAFF (2002).

Calculation of cost of planting feed grain such as barley, wheat, rice and soybean in 2000

The Japanese domestic livestock industry has used imported corn mainly as concentrate feed. In the present study, the costs were calculated under the assumption that imported corn could have been replaced with other feed grain based on the statistical data in 2000.

Barley, wheat, rice and soybean were considered here as substitute feed grains. Based on the assumption that feed grain could have been planted on unplanted cultivated land fallow for the past year in 2000, the production costs were calculated using data from the 76th Statistical Yearbook of MAFF (2002). The data on production costs per land area (Yen per 10 a) and expected yield per land area (kg per 10

Table 4. Costs for planting barley, wheat, rice and soybean as feed grain in unplanted cultivated land for past year in 2000 11.469 million tons of corn was imported in 2000 at a cost of 141,883 million yen, E=A×277,897×10/1,000, F=D×E/100, G=C×E×10/1000, H=B/A×E×1,000/1,000,000, I=H/F×1,000,000/1,000, J=H-141,883× (F/9,175)×1/100

						In case of each crop planted 100% (277,897 ha)						
	Expected yield per 10 a	Production cost per 10 a	Nitrogen to harvest	TDN	Production cost per harvest	Expected yield	Expected yield converted into TDN	Total nitrogen to harvest	Total production cost	Production cost in case of yield converted into TDN	When each crop was replaced with imported corn in case converted into TDN	Production cost when each crop was replaced with imported corn
	A kg/10 a	B yen/10 a	C kg N/100 kg	D %	B/A yen/kg	E thousand tons	F Thousand tons	G thousand tons	H million yen	I Yen/kg	F/9175 %	J million yen
Barley	327	47,096	2.17	70.4	144	909	640	20	130,878	205	7	120,986
Wheat	339	62,215	2.98	79.8	184	942	752	28	172,894	230	8	161,268
Rice	517	167,109	2.41	82.5	323	1,437	1,185	35	464,391	392	13	446,062
Soybean	173	72,655	6.86	85.8	420	481	412	33	201,906	489	4	195,527

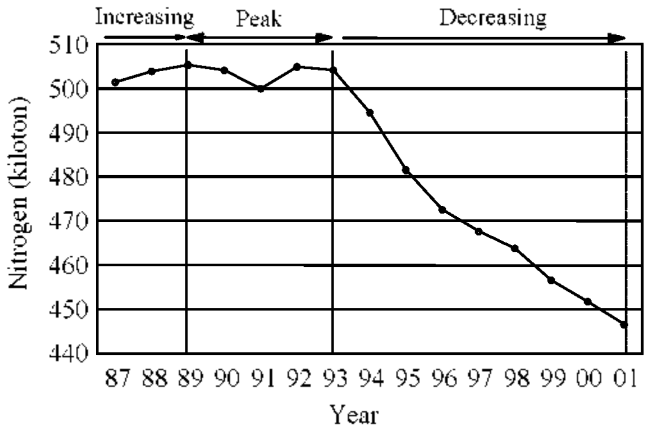

Figure 1. Nitrogen amounts excreted from the Japanese domestic livestock industry during the period 1987-2001, based on the assumption that 40% of the nitrogen from livestock was emitted as gas into the air.

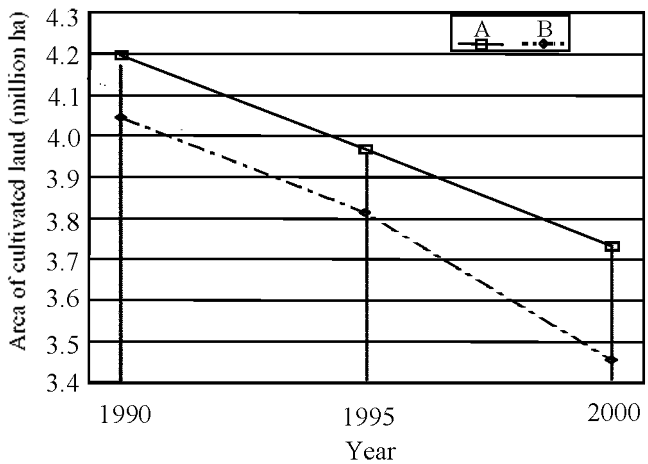

Figure 2. Changes in the total area of cultivated land under management (A) and the total area excluding unplanted paddy and upland fields left fallow for the past year (B). The area of paddy and upland fields left unplanted for the past year (A-B) increased during 1990-2000.

a) in 2000 are shown in Table 4. The cost of imported feed corn was 12,371 Yen per ton, and the import quantity was 11.469 million tons in 2000. The total cost of imported corn in 2000 is shown in Table 4. The data on Total Digestible Nutrients (TDN) of each feed grain were taken from the Japanese Feeding Standard for Swine (1998). TDN on corn was 80.0%. When converted into TDN, the amount of imported corn was 9,175,000 tons in 2000. The cost study was done for each crop to replace imported corn as concentrate feed converted into TDN in 2000.

Crops need nitrogen as fertilizer to grow. The amount of nitrogen needed by each crop was taken from data published by Komori et al. (1990). The results are shown in Table 4.

Calculation of planting barley in land left fallow the previous year (2000)

Komori et al. (1990) reported that the expected yield of barley per land area was 327 kg/10 a, and the nitrogen necessary to harvest 100 kg of barley was 2.17 kg. The N requirements for barley planted on 277,897 ha (100% of available land left fallow (2000) are shown in Table 4.

RESULTS AND DISCUSSION

Changing N from livestock wastes and N concentration on farmland

Figure 1 shows the yearly change in nitrogen, excluding gas emissions, from the domestic livestock industry. The peak period was 1989-1993. Nitrogen excreted from the domestic livestock industry per year decreased 11%, from 504,000 tons to 447,000 tons, during 1993-2001. Thus, the peak period of excreted nitrogen has passed.

Table 3 shows that Japanese domestic cultivated land area has decreased, and the area of unplanted paddy and upland fields for the year increased from 1990 until 2000. If all waste from livestock had been applied to fields as manure, the nitrogen per cultivated land area would have increased from 125 to 131 N kg/ha during 1990-2000. Figure 2 and Table 3 show that the area of cultivated land under agricultural management decreased 11%, from 4,199,000 ha to 3,734,000 ha during 1990-2000, but the

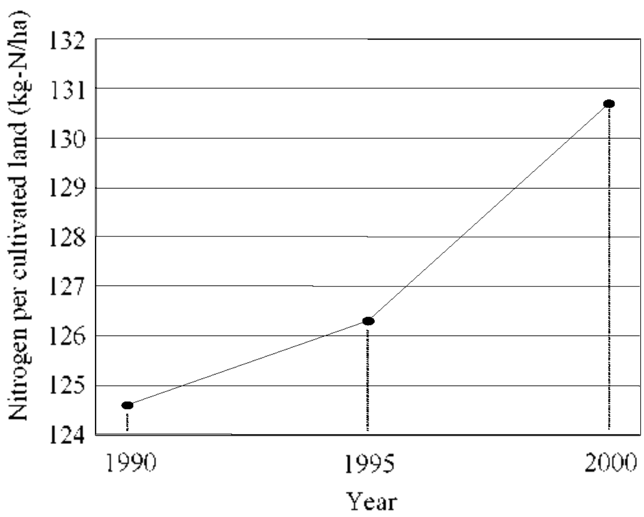

Figure 3. Changes in the amount of nitrogen from the Japanese domestic livestock industry per total area of cultivated land excluding unplanted paddy and upland fields left fallow for one year during 1990-2000, based on the assumption that all manure had been utilized on the fields as organic fertilizer.

area of paddy and upland fields left unplanted for the previous year increased 83% from 152,000 ha to 278,000 ha during the same period. Therefore, in this case, the nitrogen per net area of cultivated land would have increased 5% during 1990-2000, as shown in Figure 3.

In this study, nitrogen from animal waste is supposedly diffused into the atmosphere by gas emission (Osada, 2001) and changed into manure as organic fertilizer.

The N flow associated with the livestock industry in 2000 is shown in Figure 4. Nitrogen excreted from domestic livestock industry would have been 753,000 tons. 40% of nitrogen (301,000 tons) is supposed to diffuse into the atmosphere by gas emission and 60% (452,000 tons) is supposed to be changed into manure. Nitrogen (452,000 tons) would have been scattered as manure into fallow (34,000 tons) and cultivated land (418,000 tons). Finally 20,000 tons would have been changed to barley on fallow land as feed grain, and this circulation system could have worked on nitrogen. Therefore, the N concentration level in the soil would have been supposed to have been 14,000 tons on fallow land. This figure is based on Table 2 and 3. To make Articles 15 and 32 of the Japanese basic law concrete and attainable, Article 32 was clearly defined as follows: The State (Japanese government) shall take the necessary measures such as securing the proper use of agricultural chemicals and fertilizers and improving soil fertility through effective use of livestock manure. Full implementation of Article 32 means that since 1999, Japanese agricultural policy should aim exclusively at sustainable agricultural development. Therefore, cultivated land would be provided with fertilizers which improve the natural cyclical functions of agriculture. However, chemical

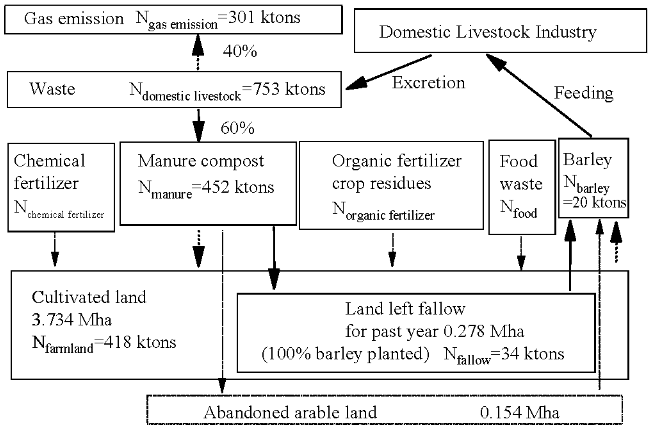

Figure 4. Nitrogen flow from the Japanese domestic livestock industry to crops in 2000, based on the assumption that 40% of the nitrogen was emitted as gas into the air and 60% was used as fertilizer. Excessive nitrogen could have been given either to land left fallow for the past year or to abandoned arable land.

fertilizer, organic fertilizer, crop residues and food waste from households or restaurants could also emerge as competitors with manure.

If nitrogen from animal waste could be utilized to grow crops, this would fulfill the natural cyclical function of agriculture.

Advantages of planting feed grain in land left fallow for a year

In this study, 40% of nitrogen from livestock industry waste was assumed to be emitted into the air. If the 60% of nitrogen from livestock waste was applied only to land left fallow for a year as manure to grow crops, it would improve the natural cyclical function of agriculture for livestock industry waste. Especially if feed grain could be planted on fallow land and used as concentrate feed or as roughage feed, it would bring 3 advantages to the domestic livestock industry. First, feed grain could raise the livestock concentrate feed self-sufficiency ratio for pig, broiler or layer poultry. Second, the feed grain stalks could raise the roughage feed self-sufficiency ratio for beef or dairy cattle. Third, if nitrogen could be utilized in nitrogenous fertilizers for feed grain grown under conditions that prevent overloading, it could reduce the risk of nitrogen overload and pollution of groundwater. Therefore, it is important to calculate the costs of planting feed grain on fallow land, and to compare cost performance for the purpose of selecting suitable feed grain.

Costs of planting barley, wheat, rice and soybean as feed grain

Table 4 shows the production cost of each feed grain if it were planted in unplanted cultivated land left fallow for the past year (2000), and if imported corn used as concentrate feed was replaced with each feed grain. It would cost 120.986 million yen for barley, 161,268 million yen for wheat. 446.062 million yen for rice, and 195,527 million yen for soybean. Therefore. barley would be the most suitable feed grain based on cost performance.

Furthermore. if the barley were planted in the land left fallow for one year and the barley stalk were given to beef cattle as roughage feed, the barley stalk could cover the amount of imported stalk and increase the roughage feed self-sufficient ratio without additional cost.

Effects of planting barley in land left fallow for one year

If, in 2000, barley had been planted in 100% of the area of land left fallow for a year (278 thousand ha), the expected yield would have been 909.000 tons. and 20.000 tons of nitrogen would have been utilized for barley from planting to harvest. as shown in Table 4 and Figure 4. This means 4% of the nitrogen excreted from livestock (452.000 tons) would have been changed to feed grain. At the same time, if converted into TDN, as Table 4 shows. 7% of the imported corn (9.175 billion tons) for feeding purposes would have been replaced with the harvested barley (640.000 tons) planted on the fallow land. In this case. the nitrogen per cultivated land area would have been 125 N kg/ha in 2000.

As already mentioned. if all manure had been applied to cultivated land and land left fallow for the past year had not been utilized. the nitrogen per cultivated land area would have increased from 125 N kg/ha to 131 N kg/ha during 1990-2000. However. if barley had been planted in unplanted cultivated land left fallow for the past year in 2000. nitrogen per cultivated land area would not have increased. but decreased from 125 to 121 N kg/ha during 1990-2000.

Avoiding nitrogen overload in cultivated land and pollution of groundwater

This effective utilization of waste would be consistent with Japanese agricultural policy as stipulated in Article 32 of the law. According to the statistics. the total area of cultivated land under agricultural management includes unplanted paddy and upland fields left fallow for one year. As we already have shown. if nitrogen from livestock waste was entirely applied without reducing the use of chemical fertilizers on cultivated land except for unplanted paddy and upland fields left fallow for one year. there could be a risk of nitrogen overload and groundwater pollution.

CONCLUSION

In Japan. the peak period of nitrogen excreted from livestock is past. However. it would be beneficial to plant feed grain on fallow land using manure as a fertilizer. and to feed the livestock with the subsequent harvest. One major benefit would be to slow the pace of cultivated land being left fallow. Furthermore, we expect planting feed grain could bring about an increase in the livestock feed self-sufficiency ratio. Barley is a feed grain more suitable than wheat, rice or soybean. on a cost-performance basis for the Japanese domestic livestock industry. 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. 59% of nitrogen from livestock. 20.000 tons out of 34,000 tons, would have been utilized as feed grain. Also, in case of conversion into TDN, 7% of the imported feed corn could have been replaced with harvested barley in 2000.

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