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An Economic Rationality of Green Manure Cropping in Large-Scale Upland Farming

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Summary

We examined the rationale of introduction and continuation of fallow green manure cropping in large-scale upland farming.

First, the decision on the introduction of fallow green manure cropping depends on the scale of farming in terms of farming area and, if introduced, the acreage of such crops represents around 5% of the total acreage.

Second, although the introduction of fallow green manure, which is a non-cash crop, causes decline in direct profitability, overall costs are reduced. Therefore, few differences in income per unit area were found among the cases of continuous, non-continuous, and non-introduction of fallow green manure cropping. In other words, there are few grounds for concern over a decline in profitability, for the halting or non continuation of fallow green manure cropping because of the availability of crop subsidies.

Third, imbalanced crop compositions are observed in the cases of non continuation fallow green manure cropping, indicating the difficulty in establishing a crop rotation. These problems are not found in the cases of continuous fallow green manure cropping despite low productivity and profitability.

1. Introduction

In the upland farming area extending mainly through the Tokachi District of Hokkaido, large-scale farming is widely practiced. In crop selection of such individual farming operations, too much weight is placed on labor-savings and more profitable crops due to the change in the economic aspect of crops. This situation prevents proper land use and establishment of a proper crop rotation system and thus causes harmful effects on land productivity such as continuous cropping hazards and declines in soil fertility. Under these circumstances, development of sustainable agriculture with the introduction of fallow green manure cropping has been attracting attention. Fallow green manure crops are regarded as useful in mitigating the factors that prevent improvement in productivity. Thus, a great deal of significance and expectation has been placed on the incorporation of fallow green manure into the crop rotation system. However, being non commercial crop, these crops rank low on the list of crops selected by individual farming operations. Therefore, the economic study of fallow green manure cropping has not gone beyond pointing out the support conditions to encourage introduction of non commercial crop and only a small number of studies have been conducted. In order to find evidence of actively promoting fallow green manure cropping, it is necessary to show conditions for such practices to become firmly established in large-scale upland farming.

Yoshinaka〔6〕 and Yoshinaka et al. 〔7〕 have made the following points clear. First, the actual state of fallow green manure cropping in individual farming operations in terms of frequency and continuity of cropping can be classified into patterns of “continuation”, “discontinuance”, and “non continuation”. Second, they clarified the criteria that determine the continuity of fallow green manure cropping based on the opinions and evaluation of introducing and halting fallow green manure cropping. As a result, continuity difference of fallow green manure cropping showed the fact that due to the problem consciousness to expansion of the scale and land utilization.

In this paper, upland farming operations in Sarabetsu Village in the Tokachi District, where such large-scale farming is widely practiced, are taken up for the study of the following three subjects. First, we demonstrate the rationale of how fallow green manure cropping is currently practiced through normative analysis, taking into account the cultivated acreage and the factors concerning land use as limiting conditions. Second, in order to show how economic efficiency, which is a criterion to discontinue fallow green manure cropping, affects the decision, we examine differences in profitability among classification patterns. Third, we study profitability of large-scale upland farming in the cases where fallow green manure cropping may or may not be established as a common practice, and suggest conditions for its establishment in cultivated acreage of 50ha or more.

2. Crop Selection in Upland Farming-rationality of fallow green manure cropping by linear programming method-

1) Purpose

One of the factors for choosing to plant fallow green manure crops is due to the heavy workload of the farm in autumn to secure wheat cropping fields. It means that the concentration of farm labor at that time makes it difficult to secure winter wheat sowing fields and as a result, continuous cropping of wheat is practiced. On the contrary, in some cases, continuous cropping is avoided as a result of the effort to secure wheat sowing fields by planting fallow green manure crops. In particular, the expansion of operational scale has been actively promoted.

Here, we seek to clarify the situation under which fallow green manure cropping is adopted, focusing on the reasons relevant to land use. We input the actual capability for continuous cropping of wheat into the linear programming model to simulate crop selection1).

2) Models

(1) Process Setting

Figure 1 describes the details of farming operation model used for analysis in this paper. It is assumed that: general upland farming crops are mainly planted in a field with a standard area of 40-70ha; the labor force is made up of three family members; and machinery and equipment used are those of the standard type and assortment in the district.

The production process is set for common products in the district: wheat (Hokushin); potatoes (for eating, processing, and starch production); sugar beets; beans (adzuki beans and red kidney beans) and sweet corn. Also, the process of fallow green manure cropping (dent corn) is added for the purpose of discussing the possibility of introducing fallow green manure cropping. For potatoes, those for eating and processing and for starch production are added; and for beans, adzuki beans, red kidney beans, and navy beans are added to each production process. Based on the above assumptions, nine processes related to crop production have been set.

(2) Profit Coefficients

Table 1 shows the profit coefficient of the production process of each crop. The profit coefficients have been set based on "*Hokkaido Nogyo Seisan Gijutsu Taikei* (Hokkaido Agricultural Production Technology System), 3rd Edition" after being

Farming area:	40-70ha	
Crops planted:	wheat, potatoes, adzuki beans, red kidney beans, sugar beets, sweet corn, and dent corn as fallow green manure	
Form of operation:	family labor of 3 persons (including hired labor)	
Machinery:		
sugar beet	＜Plantation＞	4-row 2-seater
	＜Harvester＞	1-row beet harvester
potatoes	＜Planter＞	2-row cutting planter
	＜Harvester＞	single-row 4-seater harvester
beans	＜Harvester＞	pick-up thresher
wheat,sweet corn	＜Harvest＞	outsourcing to the agricultural cooperative and companies

Figure 1 Assumed Model of Farming Operation
Source: Prepared by the authors.

Table 1 Proportional Profit by Crop

(unit: yen/10a)

	Wheat	Sugar Beets	Potatoes (for starch production)	Potatoes (for eating and processing)	Adzuki Beans	Red Kidney Beans	Navy Beans	Sweet Corn (for processing)	Fallow Green Manure
Production (kg/10a)	553	6,399	5,000	2,835	268	201	263	1,300	-
Unit Price (yen/kg)	127	16	13	42	258	250	233	35	-
Gross Income (①)	70,231	101,744	65,000	119,070	69,144	50,250	61,279	45,500	-
Fertilizer Cost	8,386	15,916	7,645	7,018	8,911	6,462	7,415	12,328	5,350
Seeding Cost	2,556	2,077	19,580	19,758	1,697	6,739	3,621	12,800	1,320
Agricultural Chemical Cost	2,956	6,524	2,044	2,594	4,001	5,676	4,133	2,469	-
Production Material Cost	-	3,923	600	600	-	-	-	-	-
Fuel Cost	581	1,075	914	1,217	670	955	1,023	833	459
Hire and Charges	18,700	-	-	-	-	-	-	-	-
Total Cost(②)	33,178	29,515	30,783	31,187	15,279	19,832	16,192	28,429	7,129
Proportional Profit 1 (①-②)	37,053	72,229	34,217	87,883	53,865	30,418	45,087	17,071	-7,129

Source: Based on "*Hokkaido Nogyo Seisan Gijutsu Taikei* (Hokkaido Agricultural Production Technology System), 3rd Edition" ; the production and unit price are adjusted taking into account the actual conditions of the region.
Note: "—" means 0.

adjusted taking into account the result of the production cost survey, the patterns of farm management shown in the Sarabetsu Village Agricultural Promotion Plan, and the agricultural cooperative's business report. The profit coefficient of each crop of the analysis model is calculated by multiplying the yield by the unit selling price and then deducting the variable cost expenditure. Since fallow green manure is directly plowed in and does not generate profit, only the costs of growing and maintenance are included.

By deducting the fixed cost from the total amount of proportional profit afterwards, the agricultural income is calculated. For this analysis, the fixed cost of upland farming is assumed to be 14.6 million yen for a farming area of 50ha and 16.6 million yen for a farming area of 60ha, as shown in the patterns of farm management in the Sarabetsu Village Agricultural Promotion Plan, to calculate the agricultural income.

(3) Resource Limitations (Limited Resources and Limited Amount)

When establishing the model, limiting conditions from a technical aspect have been set as follows, taking into account the current state of land use.

① Sugar beets are the main choice in crops. However, given the actual situation, substantial increase in the acreage of sugar beets is impossible. Therefore, the upper limit is set at 25% of the planted acreage.

② Like sugar beets, potatoes are also one of the main choices in crops. From the viewpoint of aiming at the establishment of a proper crop rotation system, it is intended to limit the acreage planted with root crops including sugar beets to 50% of the total acreage of the farming operation. Therefore, the upper limit is set at 25% of the planted acreage.

③ Potatoes for eating and processing tend to be overplanted due to their relatively high profitability per unit. However, given the actual situation, the upper limit for planting potatoes for eating and processing is set at 60% of the total acreage planted with potatoes, and the rest is to be planted with potatoes for starch production.

④ Planting limit for beans as a whole is set up to 33% of the planted acreage. However, since adzuki beans rank high in the list of crop selection for farm management due to their relatively high profitability as well as high frequency of pest infestation resulting from shortening of planting intervals, the upper limit is set at 14% of the planted acreage.

⑤ Sweet corn is a variety for processing which is shipped to food processing companies in the district, and acreage allocation and harvesting are carried out by these food processing companies. Therefore, given the actual situation, the upper limit for planting sweet corn is set at 10% of the planted acreage.

⑥ The crops which can be planted preceding winter wheat are assumed to be potatoes for eating and processing, red kidney beans among other beans, sweet corn, and fallow green manure. However, actually only early varieties of potatoes and red kidney beans can be planted preceding wheat. Therefore it is assumed that up to 80% of the acreage planted with potatoes for eating and processing, up to 80% of the acreage planted with red kidney beans, and the whole acreage of fallow green manure and sweet corn respectively, can be planted as crops preceding wheat.

⑦ Continuous cropping of wheat is actually practiced in many farming operations. In the analysis, it was studied how the crop selection changes at each stage of change in the degree of continuous cropping of winter wheat. Therefore, we studied how the crop selection changes with the changes in the degree of continuous wheat cropping within the abovementioned limit on wheat-preceding crops.

(4) Technical Coefficient

The family labor force is assumed to be made up of four persons including hired labor, working nine hours a day per person. The working hours are limited to a maximum of 288 hours per ten days assuming that the labor force participation is 90%. In the analysis model, the time divisions for the purpose of specifying labor limits are set in accordance with the patterns of farm management defined by Sarabetsu Village. Limits on working hours are set for each division of time. The labor coefficients have been adjusted assuming that the standard technical system in the region is used. As mentioned in this paper, each month is divided into the first, middle, and last ten days, taking into consideration the busy season of farming mainly of wheat.

3) Results

(1) Consistency of Analysis Models

Based on the assumptions described above, a simplex tableau is created as shown in Table 22). First, the normal model without regard to crop rotation is compared to the model with the strictest limits on planting. Table 3 shows a comparison between the actual crop composition on a field of 40-50ha (average: 45ha) and the optimal crop composition based on the computations of the model. As it shows, the acreages of adzuki beans and sugar beats are a little larger than the average and those of other crops are approximate to the actual average. Based on these results, consistency of the model is high.

Table 4 and Table 5 show how the computing result changes as the cultivated acreage are changed using parametric analysis. The former shows the cases where the limit on wheat-preceding crops is loosened (continuous cropping of wheat is allowed up to 50%) and the latter shows the cases where these limits are tightened (no continuous cropping). As the labor force is arranged, assuming that the acreage is 60ha, four kinds of crops are chosen to be planted under the conditions of loose planting limits.

(2) Crop Rotation Compliance and Crop Selection

Here, we take up pattern 3 (using green manure, no SC) to examine the relation between fallow green manure cropping and crop rotation. The actual optimum crop composition is shown in Figure 2 and Table 6. The characterization is as follows:

First, we examined the relation between the degree of continuous cropping of wheat and crop selection (wheat, beans, potatoes, sugar beets, and

Table 2 Initial Simplex Tableau Solution

				Process No.	1	2	3	4	5	6	7	8	9
	Reso-urce No.	Resource	Amount Limited		Wheat	Sugar Beets	Potatoes (for starch production)	Potatoes (for eating and processing)	Adzuki Beans	Red Kidney Beans	Navy Beans	Sweet Corn (for processing)	Fallow Green Manure (DentCorn)
	0	Profit Coefficient			37,053	72,229	34,217	87,883	53,865	30,418	45,087	17,071	-7,129
Planting Limits	1	Cultivated Acreage (10a)	200～1000	≧	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	Limit on Wheat-Preceding Crop	0	≧	0.50 ～1.00			-0.80		-0.80		-1.00	-1.00
	3	Sugar Beet Planting Limit	0	≧	-0.25	0.75	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25
	4	Potato Planting Limit①	0	≧	-0.25	-0.25	0.75	0.75	-0.25	-0.25	-0.25	-0.25	-0.25
	5	Potato Planting Limit②	0	≧			-0.60	0.40					
	6	Bean Planting Limit	0	≧	-0.33	-0.33	-0.33	-0.33	0.67	0.67	0.67	-0.33	-0.33
	7	Adzuki Bean Planting Limit	0	≧	-0.13	-0.13	-0.13	-0.13	0.88	-0.13	-0.13	-0.13	-0.13
	8	Kidney Bean Planting Limit	0	≧	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	0.90	-0.10	-0.10
	9	S.C. Planting Limit	0	≧	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	0.90	-0.10
Labor Limits	10	Feb/Last Ten Days	240	≧		1.50							
	12	Mar/Middle	240	≧	0.08	1.19							
	13	Mar/Last	258	≧		1.57	0.08	0.08					
	14	Apr/First	240	≧		0.45							
	15	Apr/Middle	226	≧		0.66	1.02	0.33					
	16	Apr/Last	288	≧	0.06	1.03	1.02	1.02					
	17	May/First	288	≧		0.91	1.11	1.80				0.40	0.43
	18	May/Middle	228	≧		0.10	0.77	0.80				0.10	0.43
	19	May/Last	262	≧	0.05	0.10			0.86	0.89	0.89		
	20	Jun/First	232	≧			0.10	0.10	0.03				
	21	Jun/Middle	249	≧	0.03	1.10	0.10			0.16	0.12	3.00	0.12
	22	Jun/Last	273	≧	0.03	0.13	0.09	0.19	1.12	1.66	1.00	0.20	
	23	Jul/First	246	≧	0.08		0.03	0.03	1.00	1.75	1.12		
	24	Jul/Middle	288	≧			0.25	0.25	1.25	0.03	1.25		
	25	Jul/Last	273	≧		0.04	0.28	0.28	0.16		0.03	0.10	
	26	Aug/First	223	≧		0.28	0.03	0.03	0.03	0.03			
	27	Aug/Middle	223	≧	0.28		0.53	0.53	0.03		0.03	0.10	0.12
	28	Aug/Last	261	≧		0.33	0.03	1.39				0.10	
	29	Sep/First	246	≧	0.24		0.03	1.39	0.03		0.03		
	30	Sep/Middle	232	≧		0.04		1.39		0.46			
	31	Sep/Last	231	≧	0.41		0.42	1.00	0.19	0.49	0.30	0.10	
	32	Oct/First	185	≧	0.03		0.63	0.25	0.22		0.30		
	33	Oct/Middle	168	≧		0.17	0.63	0.25	0.19		0.35		
	34	Oct/Last	108	≧		0.27	0.25		0.09	0.09	0.09	0.50	
	35	Nov/First	108	≧		0.25	0.25						
	36	Nov/Middle	79	≧	0.03								

Source: Based on "Hokkaido Nogyo Seisan Gijutsu Taikei (Hokkaido Agricultural Production Technology System), 3rd Edition"; adjusted, taking into account the actual conditions of the region.

Table 3 Consistency of Linear Model with Actual Data

(unit: household, ha, %)

	40～50ha		Computational Result of Pattern 1
	2005	2006	
Number of Households	45	43	-
Average Acreage	44.8	44.6	45.0
Beans	22.3	22.5	23.8
Adzuki Beans	7.7	8.1	12.5
Kidney Beans	13.5	13.2	11.3
Wheat	27.3	27.1	26.2
Sugar Beets	20.7	20.7	25.0
Potatoes	25.8	25.6	25.0
for eating and processing	12.4	12.5	10.0
for starch production	11.6	11.2	15.0
Sweet Corn	1.4	1.7	0.0
Vegetables	0.6	0.9	-
Fallow Green Manure	1.5	0.8	0.0
Others	0.3	0.6	-

Note: The model is the solution based upon the assumption of 50% continuous cropping of wheat.

dent corn). When the cultivated acreage is 50ha, a little over the average, it is possible to select crops so as not to continuously crop wheat regardless of whether or not fallow green manure is used. Second, when the acreage is 60ha, which is a realistic size that actually exists, fallow green manure is not chosen if continuous cropping is allowed to some degree (here up to 50%), whereas fallow green manure is chosen if crop rotation compliance is to be sustained, though at a low degree of 4-5%. The reason for the current extremely small ratio of fallow green manure cropping is backed by this result.

When it becomes 70ha, fallow green manure

Table 4 Parametric Computation Result (Pattern 1, Continuous Wheat Cropping 50%)

(Unit: 10a, ten thousand yen, hour, yen)

Cultivated Acreage（10a）		200	473	608	639	642	675	707	713	901	907	914
Total Proportional Profit (ten thousand yen)		1,120	2,651	3,220	3,319	3,326	3,383	3,430	3,440	3,715	3,719	3,721
Shadow Price	Kidney Beans										9,290	30,754
	Navy Beans						897	919				
	Sweet Corn (for processing)	12,326	21,346									
	Fallow Green Manure (Dent Corn)	36,526	46,222	25,207	25,187	3,511						
Shadow Cost	Cultivated Acreage (10a)	56,003	42,282	31,867	27,864	16,817	15,117	15,076	14,636	6,523	3,426	
	Limit on Wheat-Preceding Crops	5,104	5,104	21,589	21,414	39,076	41,937	42,007	40,711	10,510	4,224	3,577
	Sugar Beet Planting Limit①	37,728	17,208	16,448								
	Potato Planting Limit①	34,366										
	Potato Planting Limit②	57,749	42,190	47,773	48,105	54,686	55,752	55,633	53,834	11,915	3,365	2,874
	Adzuki Bean Planting Limit	19,364	19,364	15,800	15,838	12,798	12,305	12,291	13,410	39,508	39,635	27,939
	Kidney Bean Planting Limit	10,586	10,586	5,483	5,537					21,405	19,960	6,786
	Feb/Last (Ten Days)							4,005	5,475	39,723	46,720	47,150
	Mar/Last				10,810	4,907	3,951					
	May/First		22,550	33,571	32,887	44,936	46,887	47,141	45,512	7,550		
	Jun/Middle					7,652	8,891	8,894	8,765	5,756	5,158	5,160
	Jul/First			12,833	12,696	25,850	27,980	28,034	26,881			12,352
	Sep/Last								3,230	78,492	93,440	93,395

Souce: Computational result.

Table 5 Parametric Computational Result (Pattern 1, Continuous Wheat Cropping 0%)

(Unit: 10a, ten thousand yen, hour, yen)

Cultivated Acreage（10a）		200	473	502	556	564	640	941	1,033
Total Proportional Profit (ten thousand yen)		1,110	2,628	2,748	2,931	2,953	3,021	3,186	3,218
Shadow Price	Potatoes (for eating and processing)								31,775
	Red Kidney Beans							13,177	12,538
	Sweet Corn (for Processing)	12,609	21,748						
	Fallow Green Manure (Dent Corn)	36,809	46,634	25,279	25,275				
Shadow Cost	Cultivated Acreage (10a)	55,521	41,619	34,103	27,995	8,851	5,498	3,484	
	Limit on Wheat-Preceding Crops	3,686	3,686	17,181	16,604	32,389	32,389	32,075	35,353
	Sugar Beet Planting Limit①	38,863	18,072	19,641	20,272	13,412			
	Potato Planting Limit①	34,819							
	Potato Planting Limit②	56,615	40,850	42,603	42,213	44,829	44,829	44,617	68,133
	Bean Planting Limit			24,292					
	Adzuki Bean Planting Limit	20,498	20,498	9,702	20,606	21,647	21,647	14,386	14,782
	Kidney Bean Planting Limit	11,720	11,720	924	10,158	8,168	8,168		
	Feb/Last (Ten Days)						8,941	9,170	1,823
	May/First		22,847	35,953	35,849	51,655	51,655	51,598	67,393
	Jun/Middle					8,941	8,941	8,940	9,105
	Jul/Fist				13,923	30,242	30,242	37,793	40,931

Souce: Computational Result.

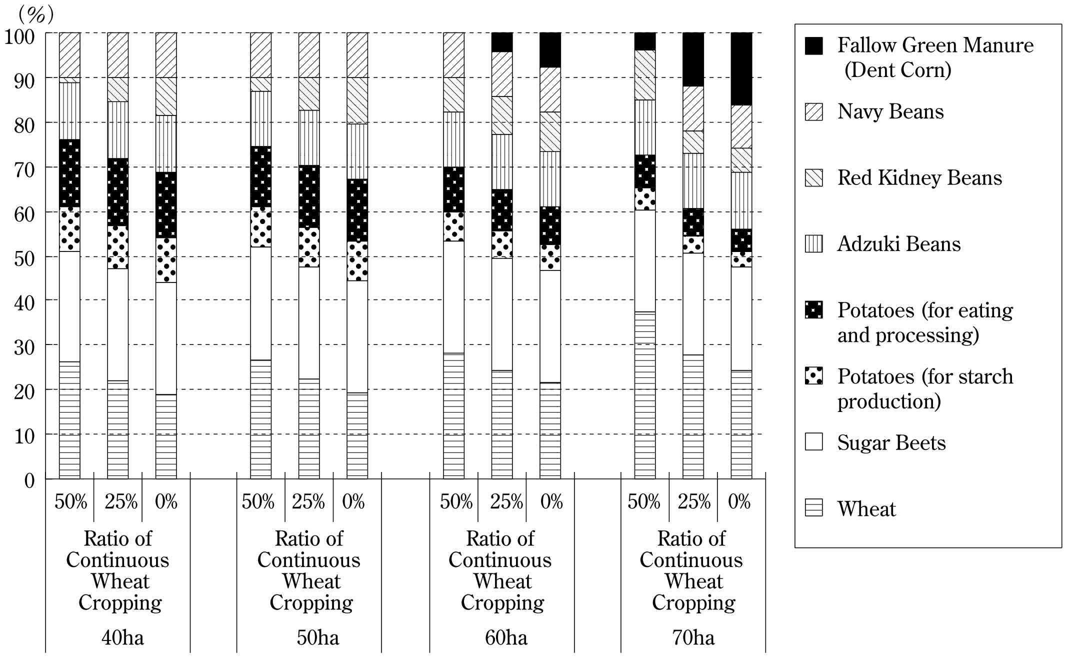

Figure 2 Changes in Optimum Crop Composition with Changes in the Ratio of Continuous Wheat Cropping (Pattern 3)

Souce: Computational Result.

Table 6 Changes in Agricultural Income of Each Model

(unit: ha, ten thousand yen)

		50ha			60ha					
		Continuation Cropping			50% Continuation Cropping	Patterns of 25% Continuation Cropping		No Continuation Cropping		
								Pattern 1 (Corn)	Pattern 3 (Green Manure)	
		50%	20%	0%		Pattern 1 (Corn)	Pattern 3 (Green Manure)		No Subsidy	Subsidy Available
Planted Acreage	Wheat	13.3	11.2	9.6	16.9	14.7	14.7	13.0	13.0	
	Sugar Beets	12.5	12.5	12.5	15.0	15.0	15.0	15.0	15.0	
	Potatoes (for starch production)	4.6	4.6	4.6	4.0	3.7	3.7	3.5	3.4	
	Potatoes (for eating)	6.9	6.9	6.9	6.0	5.6	5.5	5.2	5.2	
	Adzuki Beans	6.3	6.3	6.3	7.5	7.5	7.5	7.5	7.5	
	Red Kidney Beans	1.5	3.6	5.2	4.6	5.1	5.1	5.2	5.2	
	Navy Beans	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	
	Sweet Corn	-	-	-	-	2.0	-	1.9	-	
	Fallow Green Manure (Dent Corn)	-	-	-	-	0.5	2.5	2.7	4.7	
Cropping Ratio	Wheat	26.7	22.4	19.3	28.2	24.4	24.5	21.6	21.7	
	Sugar Beets	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
	Potatoes (for starch production)	9.1	9.1	9.1	6.6	6.2	6.2	5.8	5.7	
	Potatoes (for eating)	13.7	13.7	13.7	9.9	9.3	9.2	8.7	8.6	
	Adzuki Beans	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	
	Red Kidney Beans	3.0	7.3	10.4	7.7	8.5	8.5	8.6	8.6	
	Navy Beans	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	
	Sweet Corn	-	-	-	-	3.3	-	3.2	-	
	Fallow Green Manure (Dent Corn)	-	-	-	-	0.8	4.1	4.6	7.8	
Total Proportional Profit		2,764	2,749	2,739	3,186	3,104	3,053	2,985	2,936	2,945
Fixed Cost		1,458			1,660					
Agricultural Income		1,305	1,291	1,281	1,526	1,444	1,392	1,325	1,275	1,285
Agricultural Income per 10a		2.6	2.6	2.6	2.5	2.4	2.3	2.2	2.1	2.1

Souce: Computational Result.

Note: Fixed cost is calculated based on the data by the Sarabetsu Village Agricultural Cooperative. This is a total cost for hired labor, depreciation cost, repair cost, agricultural machinery cost,fixed property tax, land improvement cost, public charges, interest and rent.

is selected even with when repeated cultivation is allowed. On this scale, as for the fallow green manure cropping ratio which is necessary for crop rotation observance it increases to 10%.

⑶ Rationale of Fallow Green Manure Cropping

Taking into account the actual state of fallow green manure cropping practice as described above, we conducted a normative study of relation between crop selection and adoption of fallow green manure cropping. First, under the conditions where wheat tends to be overplanted, continuous wheat cropping is often practiced. When choosing a practice to avoid continuous cropping, fallow green manure cropping is an effective choice particularly for large-scale farming operations. Second, however, the acreage devoted to fallow green manure cropping is extremely small, accounting for only around 5-7% of the total planted acreage even in the cases of farming with acreage of 60ha. Third, therefore, the results reflect the extremely small acreage demonstrated in actual situations, and thus finds the rationale in terms of acreage.

Introduction of common fallow green manure crops tends to be considered as the fifth rotation. In the field survey, this tendency is observed throughout the district. However, given the introduction factors discussed in this paper, implementation of a long-term crop rotation system including fallow green manure is not always necessary under the present conditions and additional factors are required to encourage long-term crop rotation.

3．Economic Efficiency of Continuity of Fallow Green Manure Cropping

1） Continuity of Fallow Green Manure Cropping and Profitability

As already indicated, one of the criteria for deciding to stop fallow green manure cropping is the perception of economic efficiency. In other words, the intention to avoid possible reduction in gross income as a result of planting non-cash crops prevents fallow green manure cropping from being a common practice. Next, we examine whether the state of continuity affects profitability for each pattern of farm management [3)].

Table 7 is a summary of income and expenditure of each pattern.

A simple comparison between (Ⅰ) and (Ⅴ) shows that agricultural income of (Ⅰ) is greater than that of (Ⅴ) by nearly 10 million yen due to the over 10ha difference in farming area. This difference is eliminated in income per unit area and (Ⅴ)'s income per unit area exceeds that of (Ⅰ), though only slightly. However, because agricultural expenditure of (Ⅰ) is controlled at a low level, the net income of (Ⅰ) is 15,000 yen (19.3%), exceeding

Table 7 KUMIKAN (Cooperative Member's Account) Agricultural Income and Expenditure of Each Pattern (2006)

Pattern			Total	(Ⅰ)	(Ⅱ)	(Ⅲ)	(Ⅳ)	(Ⅴ)
Number of Household			138	7	28	18	56	29
Actual Figures	Average Farming Area	(ha)	45.0	56.6	48.4	39.6	45.8	40.9
	Average Sugar Production	(kg/10a)	938	957	937	967	924	943
	Total Agricultural Income	(thousand yen)	38,123	44,574	41,031	33,968	38,911	34,818
	Total Agricultural Expenditure	(thousand yen)	31,370	35,697	33,444	26,858	32,343	29,244
	Agricultural Income	(yen/10a) ①	84,850	78,157	84,298	85,004	85,093	86,433
	Agricultural Expenditure	(yen/10a) ②	69,860	62,725	68,699	67,494	70,815	72,325
	Balance	(yen/10a) ③	14,990	15,431	15,599	17,510	14,278	14,108
	KUMIKAN Income Ratio	(%)	17.2	19.3	18.2	20.4	16.1	16.1
Coefficient of Variation	Average Cultivated Area	(ha)	(0.28)	(0.23)	(0.26)	(0.22)	(0.29)	(0.26)
	Average Sugar Production	(kg/10a)	(0.13)	(0.22)	(0.10)	(0.09)	(0.14)	(0.12)
	Agricultural Income	(yen/10a)	(0.13)	(0.09)	(0.12)	(0.12)	(0.14)	(0.10)
	Agricultural Expenditure	(yen/10a)	(0.12)	(0.12)	(0.11)	(0.11)	(0.12)	(0.10)
	Balance	(yen/10a)	(0.46)	(0.59)	(0.36)	(0.28)	(0.56)	(0.41)
	KUMIKAN Income Ratio	(%)	(0.42)	(0.60)	(0.30)	(0.22)	(0.51)	(0.35)

Source: Based on data by the Sarabetsu Village Agricultural Cooperative.
Note: Balance (③)＝①-②, KUMIKAN Income Ratio＝③/①×100.

14,000 yen (16.1%) of (Ⅴ). Although a decline in profit on a single-year basis is indicated, the difference seems to be eliminated in profitability per 10a.

Concern over a decline in gross profit resulted from fallow green manure cropping, which is mentioned as a reason to halt cropping in the non-continuous cases, is supported by the differences in profit in a single year among different patterns. However, when it comes to the net income ratio, the ratio of continuous cases may be higher than those of others, indicating there are few grounds for reducing the acreage or halting planting of fallow green manure out of concern over a decline in profitability or by reason of availability of subsidies. Rather, this fact should be highly considered as grounds for the introduction of fallow green manure.

2) Difference in Profitability between Continuation and Non Continuation Cases of Fallow Green Manure Cropping in Large-Scale Farming Operations

In this paper, we analyzed factors that lead to introduction of fallow green manure and factors that lead to discontinuation of the same with particular attention paid to the continuity of fallow green manure cropping in terms of time for the purpose of-presenting conditions for the continuation of fallow green manure cropping. In this analysis, we mentioned secure a gross income through scale expansion as well as changes in crop selection and dealing with of overplanting as the factors that facilitate introduction of fallow green manure cropping. As discussed above, in order to predict future directions of land use by large-scale upland farming operations in particular, we believe it is important to examine relation between crop selection and profitability.

In Table 8, farming operations with farming areas of 50ha or more are classified into a group consisting of those of patterns (Ⅰ) and (Ⅱ) that continues fallow green manure cropping, which is called the "established group", and another group consisting of those of patterns (Ⅲ), (Ⅳ) and (Ⅴ) that do not continue fallow green manure cropping, which is called the "non-established group", to examine the profitability of each group. When focusing on large-scale upland farming operations, differences are found in the following points.

First, in the non-established group, some crops such as wheat and potatoes, in particular, tend to be overplanted in many cases. A similar situation is also observed in the established group. However suggesting that most operations have little problem in establishing the crop rotation system.

Second, in the non-established groups, there are many operations whose financial position in terms of income and expenditure is weak. The reason behind this is that the level of unit yield is also relatively low in many operations.

In Table 9, farming operations are classified and analyzed in relation to crop selection. They are classified using the simple crop rotation value as an indicator of long-term continuation of crop rotation. Operations with low value are considered to have imbalanced cropping patterns, and agricultural income and expenditure are shown for each classification[4).

The features apparent on the table is that, first, imbalanced cropping patterns are observed regardless of whether or not fallow green manure cropping is established, and in these cases wheat and potatoes are particularly overplanted. Second, the position of agricultural income and expenditure as well as the net income ratio differ whether fallow green manure cropping is established or the cropping pattern is proper or imbalanced. Third, one of the factors of these differences is the difference in the level of unit yield. The average sugar production of sugar beets decreases in the same order as the above-mentioned order of agricultural income and expenditure. Based on these results, there is a concern over decline in productivity of the group in which fallow green manure cropping is not established, particularly in the cases where the crop rotation system is disrupted.

Table 8 Cropping Ratio and KUMIKAN Agricultural Income and Expenditure of Large-Scale Operations (2006)

			Established (Ⅰ・Ⅱ)		Non-established (Ⅲ・Ⅳ・Ⅴ)	
			Average	Variation Coefficient	Average	Variation Coefficient
No. of Household			20		27	
Average Farming Area		(ha)	59.2	(0.15)	58.0	(0.15)
Simple Crop Rotation Value			3.5	(0.11)	3.2	(0.13)
Average Sugar Production		(kg/10a)	997.4	(0.07)	959.1	(0.10)
Cropping Ratio (%)	Wheat		27.1	(0.16)	27.9	(0.22)
	Potatoes		23.9	(0.19)	26.5	(0.26)
	Beans		19.7	(0.29)	21.5	(0.37)
	Sugar Beets		20.3	(0.13)	19.2	(0.17)
	Others		9.1	(0.58)	4.9	(1.20)
KUMIKAN Agricultural Income and Expenditure	Total Agricultural Income	(thousand yen)	50,394	(0.18)	47,574	(0.14)
	Total Agricultural Expenditure	(thousand yen)	40,803	(0.17)	39,991	(0.13)
	Agricultural Income	(yen/10a)	85,227	(0.12)	82,748	(0.13)
	Agricultural Expenditure	(yen/10a)	68,899	(0.09)	69,469	(0.11)
	Balance	(yen/10a)	16,329	(0.32)	13,280	(0.54)
	KUMIKAN Income Ratio	(%)	18.8	(0.25)	15.5	(0.45)

Source: Based on data by the Sarabetsu Village Agricultural Cooperative
Note:1) Large-scale operations are those with a farming area of 50ha or more.
2) Simple Crop Rotation Value＝total planted acreage/acreage planted with the largest crop

Table 9 Establishment of Fallow Green Manure Cropping, Imbalance in Cropping Composition, and KUMIKAN Agricultural Income and Expenditure of Large-Scale Operations (2006)

Imbalance in Crop Composition			Established (Ⅰ・Ⅱ)				Non-established (Ⅲ・Ⅳ・Ⅴ)			
			Small		Large		Small		Large	
			Average	Variation Coefficient	Average	Variation Coefficient	Average	Variation Coefficient	Average	Variation Coefficient
No. of Household			10		10		12		16	
Average Farming Area		(ha)	58.5	(0.12)	60.0	(0.17)	56.3	(0.10)	59.3	(0.17)
Simple Crop Rotation Value			3.8	(0.07)	3.2	(0.06)	3.6	(0.06)	2.9	(0.10)
Average Sugar Production		(kg/10a)	1019.5	(0.05)	975.4	(0.08)	969.1	(0.09)	951.6	(0.11)
Cropping Ratio (%)	Wheat		24.0	(0.12)	30.2	(0.11)	25.5	(0.12)	29.7	(0.24)
	Potatoes		22.9	(0.16)	24.9	(0.20)	26.2	(0.11)	26.8	(0.32)
	Beans		22.8	(0.12)	16.6	(0.39)	23.9	(0.14)	19.7	(0.50)
	Sugar Beets		19.7	(0.14)	20.9	(0.12)	18.7	(0.20)	19.6	(0.15)
	Others		10.7	(0.53)	7.5	(0.56)	5.6	(1.02)	4.3	(1.37)
KUMIKAN Agricultural Income and Expenditure	Total Agricultural Income	(thousand yen)	49,047	(0.19)	51,741	(0.16)	46,906	(0.14)	48,075	(0.14)
	Total Agricultural Expenditure	(thousand yen)	39,285	(0.19)	42,321	(0.14)	38,612	(0.13)	41,026	(0.13)
	Agricultural Income	(yen/10a)	83,367	(0.10)	87,088	(0.13)	83,741	(0.14)	82,004	(0.12)
	Agricultural Expenditure	(yen/10a)	66,767	(0.09)	71,030	(0.08)	68,901	(0.13)	69,894	(0.10)
	Balance	(yen/10a)	16,600	(0.26)	16,058	(0.37)	14,839	(0.45)	12,110	(0.61)
	KUMIKAN Income Ratio	(%)	19.8	(0.21)	17.9	(0.27)	17.3	(0.37)	14.2	(0.50)

Source: Based on data by the Sarabetsu Village Agricultural Cooperative
Note:1) Large-scale operations are those with a farming area of 50ha or more.
2) The degree of imbalance in crop composition is based on the calculation : Simple Crop Rotation Value＝total planted acreage/acreage planted with the largest crop.

4. Conclusion

The objectives of this paper are: first, to demonstrate the rationale of how fallow green manure cropping is currently practiced through normative analysis, taking into account the cultivated acreage shown in the previous chapter and the factors concerning land use as limiting conditions; second, to examine differences in profitability among classification patterns in order to show whether or not the economic efficiency, which is a criterion for deciding to discontinue fallow green manure cropping, affects the decision; and third, to study profitability of large-scale upland farming in the cases where fallow green manure cropping is established as a common practice or not, and to suggest conditions for the practice of fallow green manure cropping to be firmly established in upland farming operations of 50ha or more.

The results of the analysis are as follows.

First, normative analysis taking into account the factors that determine the continuity of fallow green manure cropping demonstrates the rationale of actual practice. In relation to continuous cropping of wheat, the following points are made clear. First, assuming that farmers behave based on the awareness of proper crop rotation, the scale of management in terms of farming area affects the decision whether or not to choose fallow green manure. Second, when fallow green manure is selected, the cropping acreage with 60ha even with 5-7% and 70ha is 10%. This became a result which is similar to the actual condition. Third, therefore, implementation of a long-term crop rotation system including fallow green manure is not always necessary under present conditions. This means, considering the current purpose of fallow green manure cropping, allocating 10% or 20% of total farming area to fallow green manure cropping is not necessary.

Next, we examined profitability of each classified pattern to verify the decline in gross profit which is a factor that triggers the decision to discontinue fallow green manure cropping. The result indicates that profit may decline depending on how firmly the cropping of fallow green manure of non commercial crop. But, because cost has decreased above that, difference of the agricultural income due to fallow green manure cropping continuity is not seen.

Next, large-scale farming is seen, difference of agricultural income becoming rank depending upon continuity of fallow green manure cropping and cropping balance, it had appeared. As for the primary factor which this difference occurs, it can think that it is difference of land productivity. With the case where especially cropping balance has been disordered, it feels concern that productivity has decreased.

In Hokkaido, further scale expansion of upland farming is expected. The land use by large-scale operations tends to devote excessively large portions of land to certain kinds of crops. In such cases, fallow green manure cropping has significance in that, if introduced even at a few percent of the field, it would improve the balance of cropping among the existing four kinds of crops and enable establishment of a stable 4-year crop rotation system. Introduction and establishment of fallow green manure cropping should be a strategic choice for large-scale upland farming.

Notes

1) There is a great deal of research analyzing upland farming using the linear programming methods. Their analyses are different from this paper in that this paper's analysis simulates the use of resources over the whole operation by changing planting limits for the establishment of a crop rotation system, i.e. simulating cases where four-year rotations are considered and not considered. Consequently, fallow green manure, whose profit coefficient is negative, should not be chosen. However, in the cases where planting limits are tightened and other crops are planted to the maximum allowed, if the planned acreage has not been planted, fallow green manure is chosen within the extent of available resources to achieve the planned acreage. This process is described in the above-mentioned analyses.
2) Actual computing has been performed using XLP by Oishi〔3〕.
3) Based on Yoshinaka〔6〕, upland farming operations in Sarabetsu Village are classed into the following patterns according to the continuity of fallow green manure cropping in the 1980s (first period) and the 1990s (second period).
   (Ⅰ) Frequency of green manure cropping is high in both periods.
   (Ⅱ) Frequency of green manure cropping is low in

the first period and high in the second period.

(Ⅲ) Frequency of green manure cropping is high in the first period and low in the second period.

(Ⅳ) Frequency of green manure cropping is low in both periods.

(Ⅴ) Fallow green manure has not been cropped throughout the analysis period.

4) The simple crop rotation value shows that the crop which is most overplanted in each operation is planted once in a given number of years. For example, in an operation managing a farming area of 40ha, if the acreage of the most overplanted crop is 10ha, the value is 4.0, which means "4-year rotation", and if the acreage is 15ha, it is "2.7-year rotation". In this way the frequency is expressed in values. Refer to Shiga〔5〕 for details. However, as mentioned in the above-named work for reference, the simple crop rotation value does not show the state of crop rotation in its original meaning, which involves changing crops grown on the same field, but it shows "the intensity of the tendency toward overplanting".

References

〔1〕Amano,T., "Tokachi Hatasaku Keiei ni okeru Dozyou Zyouken to Sakumotsu Hensei", *Research bulletin of the Hokkaido National Agricultural Experiment Station,* No.138, 1983, pp.63-85.

〔2〕Nishimura,N., "Daikibo Hatasaku ni okeru Keieikibo Kakudai to Sakutsuke Houshiki no Saihen Houkou", *Nougyou Keiei Tsuushin*, Vol.172, 1992, pp.26-29.

〔3〕Oishi,W., "Linear Programming "XLP" for Farming Planning", *Agricultural information research,* Vol.15, No.3, 2006, pp.319-330.

〔4〕Sasaki,T., "Shinkisakumotsu Dounyuu niyoru Keieitenkai no Hyouka", Matsubara,S., *Senryakuteki Nougyou no tameno Ishikettei*, Nourin Toukei Kyoukai, 1997, pp.73-92.

〔5〕Shiga,E., "Daikibo Hatasaku Nougyou no Kouzou henka to Tochiriyou", Yoshida,H., *Nougyou Gizyutsu to Keiei no Hatten,* Nourin Toukei Kyoukai, 2002, pp.25-36.

〔6〕Yoshinaka,S. and Shiga,E., "The Actual Condition of Green Fertilizer Use of Fallow-field in Upland Farming", *Japanese Journal of Farm Management*, Vol.43, No.1, 2005, pp.159-162.

〔7〕Yoshinaka,S., "A Study of Act to Green Manure Fallow System in Upland Farming", *Japanese Journal of Farm Management,* Vol.45, No.2, 2007, pp.57-62.