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Comparison of Yields among Several Cropping Systems on Alluvial Paddy Fields in the Southern Region of Iwate Prefecture, Japan

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1. Introduction :

Overstock of rice in the Japanese food control system resulted in the restriction of the use of paddy fields for rice production. 20－30% of paddy fields in Japan are now used for upland crops. However, the world population explosion holds the perils of famine and malnutrition World agriculture is always aiming for further increase of food production which is the basic nutrient for the sustenance of human life (Wharton, 1977). A contradiction is occurring in the Japanese agriculture system, because, security of food supply potential is essential domestically and internationally. More research should be done in the future.

Iwate Prefecture has 1528 thousand (M) ha, in which 1167 M ha are used for forest,

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174 M ha for arable land, and the remainder for other purposes. Arable land includes 71.5 M ha of upland and 102.7 M ha of paddy field (Statistics and Information Department, 1986). Paddy field used for rice cultivation is about 75.6 M ha and the residual 27.1 M ha is restricted to rice production and is used for upland cropping (Iwate Statistical Soc. of Agr. and Forestry, 1988). Historically, paddy fields are situated in optimum conditions of water supply and soil fertility. As Ritchie (1983) suggested, there might be greater potential for increasing production through improvement in yield than in expansion to new arable land. In these circumstances, there seems to be 2 ways to secure of food supply potential. One is an increase of individual crop yield. Another is the increase of total production from a unit area which can be done by multiple cropping (Andrews and Kassam, 1976).

We need a change of conception now. Japanese agriculture was built mainly on paddy fields and rice production. Furthermore, paddy fields have been useful for flood control and ground water supply (Honda, 1982). We should maintain and make the best use of such a field base. However, not only rice but also upland crop production on paddy fields should be studied. Upland crop cultivation differs distinctly from the condition of continuous paddy-rice cultivation. As Ohkubo (1976) insisted, rotational cropping or cropping system is essential for upland crops. In his book he wrote about the function of rotation in upland crops as a water in paddy rice He reminds us about the role of water which enabled continuous paddy-rice cultivation for two thousand year.

Cropping system in Japan were put together by Ohkubo (1976), but experiments on long-term upland cropping system on paddy fields are few and the effects of upland-paddy rotational land use on soil productivity are scarcely researched in the Tohoku district. Such experiments should be done in each district, because the climate, soil, crops, and the cropping system itself are different in each district, which means the results will differ.

Our research was conducted over 8 years to determine adequate cropping systems for high and durable yields of upland crops and also paddy rice in the cropping system on alluvial paddy fields in the southern region of Iwate Prefecture, Japan. This study has been linked with the integrated aid policies subject named of "Use and reorganization technique of alluvial paddy field on the basis of wheat and soybean (1980-1983)" and "High and stable production methods of upland crops by upland and paddy rotational land use for the large-scale upland crop production groups on paddy fields (1984-1987)". We studied the results and problems of several systems on the yields and total land productivity. We compiled the results of 8 years of research work and round off double cropping system on the basis of wheat and soybean as central figure. Conclusions concerning about soil fertilities will be reported in another paper.

2. Materials and Methods

1) Cropping Systems and Varieties of Each Section

The cropping system experiment was continued for 8 years on alluvial paddy field in Kennan Branch of Iwate Agricultural Experiment Station (KN Branch) which is situated at 39"10' north latitude and 141"20' east longitude. This field named "2 gouden" (Paddy Field No.2), was divided into 10 sections in 1980 from 30a uniform paddy field as shown in Figure 1. Elevation of the field was 40m. Topography is lowland formed by the Kitakami

River and its tributary. Average temperature and total precipitation from 1980 to 1987 were 10.6C and 1224mm respectively (Tables attached 1 and 2) . Average days of continuous snow cover was 69. Soil type is well-drained, brown-colored alluvial clay loam which has thick effective horizon for root elongation. Soil physical and chemical properties were satisfactory not only in topsoil but also in subsoil.

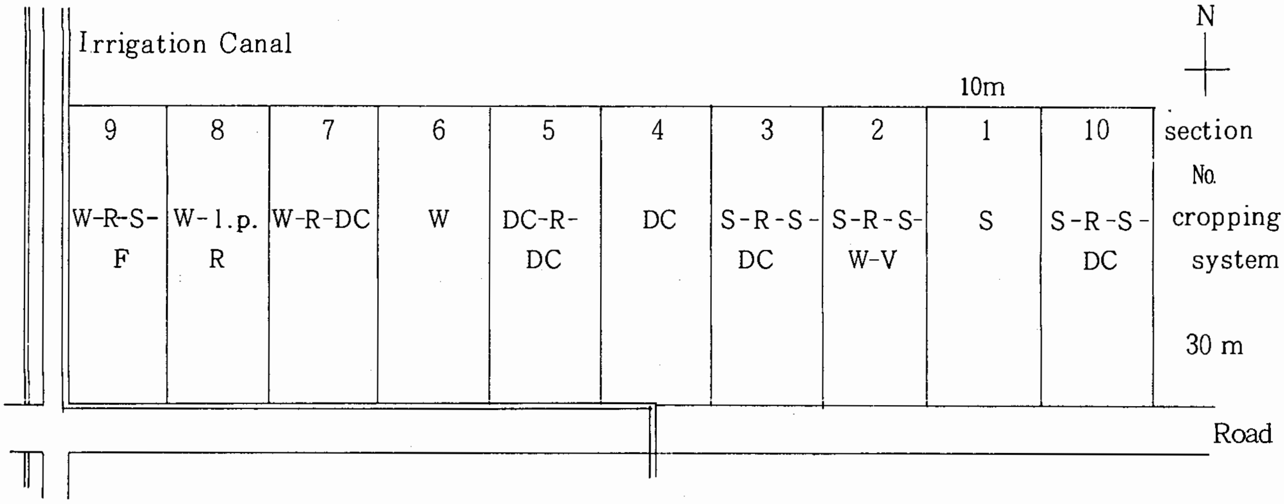

Fig 1　Map of the cropping system experiments on Field No.2 in Kennan Branch
Abbreviations are same as Table 1

Table 1　Cropping system of esch section in field No.2

Sec. No.	Cropping system	1980 Su	1980 Wi	1981 Su	1981 Wi	1982 Su	1982 Wi	1983 Su	1983 Wi	1984 Su	1984 Wi	1985 Su	1985 Wi	1986 Su	1986 Wi	1987 Su	1987 Wi
10	S-R-S-DC	S		S		R		R		S	W	S	W	S		R	
1	S	S		S		S		S		S		S		S		S	
2	S-R-S-W-V	S		S		R		S		S	W	C.C.	Ga.	Carrot		R	W
3	S-R-S-DC	S		S		S		R		S	W	S	W	S		R	W
4	DC	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W
5	DC-R-DC	S	W	S	W	S		R	W	S	W	S		R	W	S	W
6	W		W		W		W		W		W		W		W		W
7	W-R-DC		W		W			R	W		W	S	W	S	W	S	
8	W-l.p.R	S	W	l.p.R	W	l.p.R	W	l.p.R	W		W	l.p.R		S	W	l.p.R	S
9	W-R-S-F		W		W	S	B	l.p.R	W	S	Rye	Dent	W	Sudax		R	W

Su=summer crops, Wi= Winter crops
S =soybean, W =Winter Wheat, DC = Soybean and Wheat Double Cropping
B=Barley, R = Rice, F = Forage crops, l.p.R= late planted rice after wheat or barley,
V = Vegetables, C.C.= Chinese cabbage, Ga= Garlic,
Section No.1 and 6 are mono-cropping of soybean and wheat, respectively.

As shown in Table 1, main systems of each sections were mono-cropping (MC [repeated cultivation of the same crop on the same field]) of soybean and wheat or double cropping (DC) until 1983. But some vegetables and forage crops were added after 1984, due to the policy aid program. In both systems, effects of paddy rice cultivation on upland crops were examined.

Sections No.1 and No.6 were complete MC of soybean and wheat, respectively. Soybean variety used was Nanbushirome which was developed by Tohoku Agr. Exp. Stn. and registered as an encouragement variety in Iwate Prefecture in 1977. Wheat variety used was Nanbukomugi which is the earliest wheat variety in this region, developed by previous Morioka Agr. Exp. Stn. and was registered as an encouragement variety in Iwate Prefecture in 1951. Both varieties are in general use in this region.

Sections No.2, 3, 10 were examined for the effect of paddy-rice cultivation in soybean mono-cropping in 1982 and 1983. Section No.7 was examined for the effect of paddy-rice cultivation in wheat mono-cropping in 1983. Rice variety used for rotational paddy fields was mainly Koganehikari, which has high yield and collapse resistance, developed by Furukawa Agr. Exp. Stn. and was registered as an encouragement variety in Iwate Prefecture in 1982. But rice variety Sasanishiki, which has good taste and quality but is susceptible to collaption, was used in section No.10. Sasanishiki was developed by Furukawa Agr. Exp. Stn. and was registered as an encouragement variety in Iwate Prefecture in 1964.

Secton No.4 was wheat and soybean double-cropping system (DC). This system has been recognized as the most successful system for grain production in southern US (Lewis and Phillips 1976) and accounted for 16% of the total U.S. soybean acreage in 1982 (Wesley and Cooke 1988). However, temperature needed for maturing normal soybean variety after wheat was less in this area. Therefore, we mostly used the new variety Wasesuzunari which was the earliest maturing and was registered as an encouragement variety in Iwate Prefecture in 1983. This variety was developed by the Kariwano-branch of Tohoku Agr. Exp. Stn. for the special use such as DC system. It was registerd as "Soybean Norin 78" in 1983 (Hashimoto et al., 1985). But there was no wheat variety earlier than Nanbukomugi which is the same as section No.6.

Sections No.5, 3, 7 were used for examination of the time space of rice cultivation on the wheat-soybean DC system for 2, 3, 4 years, respectively, from 1983 to 1987. Varieties used were Wasesuzunari for soybean, Nanbukomugi for wheat and Koganehikari for rice. Introduction of green soybean on the DC system for the purpose of earlier harvesting of summer crop and seeding of wheat, was examined in 1987 on the half of section No. 4 and 5.

Section No.8 was used mainly for wheat and late planted paddy-rice on double-cropping system which was conducted for 5 years. This system is common in southern Honshu, however, lower temperature in Tohoku district had prevented further extension. Normal rice varieties in this area were unsuitable for this system, so the earliest rice variety Kochiminori was used. This variety was developed in Fujisaka Branch of Aomori Agr. Exp. Stn. and was registered as a quasi-encouragement rice variety in the northern part of Iwate Prefecture in 1983.

Section No.9 was used for various forage crops from 1984 to 1986, with the intention of extending to cattle raisers who own paddy fields. Tops of the forage crops were removed but roots and residues were mixed with the soil.

Eliminating the weather factor in the comparison the cropping systems, making the reference fields of standard cultivation might be useful. We selected the upland examination fields to determine the recommended varieties as the reference of wheat and soybean, and the paddy field for yearly crop report as a reference of paddy-rice in KN Branch. Reference wheat and soybean were cropped by the 3-field upland rotational system which contained green manure plowed in. But there was no reference for DC of soybean which was planted in July after the wheat harvest. So we used the same soybean variety Wasesuzunari, which was planted in May on the upland examination field, as the temporary reference.

2) Cultivation Methods :

In all sections, seed bed preparation for upland crops were done by rotary tilling. Wheat seeds were spread on the field and were mixed with top-soil by rotary at a depth of about 5cm. Seeding rate was 10kg／10a. Weed control of wheat was done by use of herbicides (chloro-IPC in autumn and actinol in spring) . Soybean seeding was done by bean-seeder or by hand with row width of 70cm in May and 60-65cm in July. Seeding density was 9,500-14,000／10 a in May and about 20,000 in June. Weed control of soybean was done by use of herbicides (bentiocurve and prometrin after seeding) and intertillage. Rice seedlings were grown in a vinyl plastic hothouse about 20 days and were transplanted by machine to the evenly prepared paddy field.

Crop growth and yields of each sections were measured yearly. Machines used for harvesting were a combine harvester for wheat, bean harvester for soybean, binder cutting and harvester threshing for rice. Wheat straw and residue were scattered on the surface and were mixed with topsoil. But rice straw was removed from the field for operational reasons.

Cultivation methods in reference fields were same as above except for stripe (about 70cm) seeding of the wheat by hand with the seeding rate of 6kg／10a.

3) Invested Fertilizers and Organic Materials :

Fertilizer Nitrogen (N) , Phosphorous (P) , and Potassium (K) invested to each section are shown in Tables 2, 3, and 4, respectively. Fertilizers used were mainly ammonium sulfate for N, super phosphate for P, and potassium chloride for K. But complex fertilizers were used after 1985, especially for vegetables.

P and K levels were about 10kg／10a in P_2O_5 and K_2O form, respectively, for each crops. But N level differed greatly according to crop. The N level was lowest in MC soybean on section No.1 or reference field and was highest in vegetables on section No.2. The N level of DC soybean was double that of MC soybean initially, but increased to 6 to 10 kgN／10a after 1985 because it was discovered by other experiments that DC soybean was short in growth period and needed more basal N for the rapid growth in early stages (Ono et al. 1986) .

N levels for wheat were 5+4kgN／10a (5kg is basal and +4kg is top-dressing in spring) in each section and added topdressing 2kgN／10a at meiosis stage after 1986. Reference field had higher soil fertility and N levels for wheat was 4+2kgN／10a.

N levels of rice in the reference field were 4kgN／10a of basal and 2kg of top-dressing at meiosis stage for Sasanishiki and 6kgN／10a of basal and 2kg of top-dressing at panicle-formation stage for Koganehikari. Basal N levels in rotational rice after upland cropping were half of the amount in reference rice, because soil inorganic N level and root activity in

Table 2　Nitrogen fertilizer invested to each section from 1980 to 1987 (kg N／10a)

Sec. No.	Cropping systems	1980 Su	1980 Wi	1981 Su	1981 Wi	1982 Su	1982 Wi	1983 Su	1983 Wi	1984 Su	1984 Wi	1985 Su	1985 Wi	1986 Su	1986 Wi	1987 Su	SUM
10	S-R-S-DC	2		4		6		6		5	9	6	9	9		10	66
1	S	2		2		2		2		2		2		2		2	16
2	S-R-S-W-V	2		2		6		2		2	9	23	35	24		8	113
3	S-R-S-DC	2		2		2		6		5	9	6	9	9		10	60
4	DC	2	9	4	9	4	9	4	9	5	9	6	9	9	11	10	109
5	DC-R-DC	2	9	4	9	4		6	9	5	9	6		10	11	10	94
6	W		9		9		9		9		9		9		11		65
7	W-R-DC		9		9		6		9		9	6	9	6	11	9	83
8	W-l.p.R			4	9	4	9	4	9		9	6		2	11	6	73
9	W-R-S-F		9		9		9	5	9	5	9	10	9	8		10	92
Ref.	W (Nk)		6		6		6		6		6		6		6		42
	S (N, W)	2.4		2.4		2.4		2.4		2.4		2.4		2		2.4	18.8
	R (Sa)	6		6		6		6		6		6		6		6	48
	R (Kg)	8		8		8		8		8		8		8		8	64

Su=summer crops, Wi=winter crops, Parentheses show the varieties of reference field,
Nk=Nanbukomugi, N=Nanbushirome, W=Wasesuzunari, Sa=Sasanishiki, Kg=Koganehikari.

Tabie 3　Phosphate fertilizer invested to each section from 1980 to 1987 (kg P_2O_5／10a)

Sec. No.	Cropping systems	1980 Su	1980 Wi	1981 Su	1981 Wi	1982 Su	1982 Wi	1983 Su	1983 Wi	1984 Su	1984 Wi	1985 Su	1985 Wi	1986 Su	1986 Wi	1987 Su	SUM
10	S-R-S-DC	10		10		10		10		10	10	10	10	10		10	100
1	S	10		10		10		10		10		10		10		10	80
2	S-R-S-W-V	10		10		10		10		10	10	10	33	36		10	149
3	S-R-S-DC	10		10		10		10		10	10	10	10	10		10	100
4	DC	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	150
5	DC-R-DC	10	10	10	10	10		10	10	10	10	10		10	10	10	130
6	W		10		10		10		10		10		10		10		70
7	W-R-DC		10		10		10		10		10	10	10	10	10	10	100
8	W-l.p.R			10	10	10	10	10	10		10	10		10	10	10	110
9	W-R-S-F		10		10		10	10	10	10	10	10	10	8		10	108
Ref.	W (Nk)		10		10		10		10		10		10		10		70
	S (N, W)	10		10		10		10		10		10		15		10	75
	R (Sa, Kg)	12		12		12		12		12		12		12		12	96

P is basal fertilizer only

Table 4 Potassium fertilizer invested to each section from 1980 to 1987 (kg K_2O／10a)

Sec. No.	Cropping systems	1980 Su	1980 Wi	1981 Su	1981 Wi	1982 Su	1982 Wi	1983 Su	1983 Wi	1984 Su	1984 Wi	1985 Su	1985 Wi	1986 Su	1986 Wi	1987 Su	SUM
10	S-R-S-DC	10		10		10		10		10	10	10	10	10		10	100
1	S	10		10		10		10		10		10		10		10	80
2	S-R-S-W-V	10		10		10		10		10	10	18	31	26		10	145
3	S-R-S-DC	10		10		10		10		10	10	10	10	10		10	100
4	DC	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	150
5	DC-R-DC	10	10	10	10	10		10	10	10	10	10		10	10	10	130
6	W		10		10		10		10		10		10		10		70
7	W-R-DC		10		10		10		10		10	10	10	10	10	10	100
8	W-l.p.R			10	10	10	10	10	10		10	10		10	10	10	110
9	W-R-S-F		10		10		10	10	10	10	10	10	10	8		10	108
Ref.	W (Nk)		10		10		10		10		10		10		10		70
	S (N, W)	10		10		10		10		11		10		10		10	81
	S (Sa, Kg)	12		12		12		12		12		12		12		12	96

such fields were far greater than in continuous paddy field (Ono et al. 1985). But topdressing N was at the same level.

Table 5 shows bulk weight of farm yard manure (FYM) applied to each section, which was made of the complex of rice straw and dung of cows fattened at the nearby Taneyama stock farm. FYM was applied annually to sections No,1,2,3 and 10 from 1980 to 1985. Largest application of FYM was 5t／10a to the vegetables in section No,2 in 1985. Other sections had zero

Table 5 Bulk weight of Farm Yard Manure invested from 1980 to 1987 (kg／10a)

Section No.	Cropping systems	1980	1981	1982	1983	1984	1985	1986	1987	SUM
10	S-R-S-DC	1500	1500	1500	1200	1200	0	0	0	6900
1	S	1500	1500	1500	1200	1200	1200	1200	1200	10500
2	S-R-S-W-V	1500	1500	1500	1200	1200	5000	3000	0	14900
3	S-R-S-DC	1500	1500	1500	1200	1200	0	0	0	6900
4	DC	1500	0	0	0	0	0	0	0	1500
5	DC-R-DC	1500	0	0	1200	0	0	0	0	2700
6	W	0	0	0	0	0	0	0	0	0
7	W-R-DC	0	0	0	1200	0	0	0	0	1200
8	W-l.p.R	1500	0	0	0	0	0	0	0	1500
9	W-R-S-F	0	0	0	0	0	0	0	0	0
Ref.	W (Nk)	1000	1000	1000	1000	1000	1000	1000	1000	8000
	S (N, W)	1000	1000	1000	1200	1200	GM	GM	GM	5400
	R (Sa, Kg)	2000	2000	2000	2000	1200	1200	1200	1200	12800

GM=green manure (turnip in 1985 and oats in 1986, 1987) or little amount of FYM as shown in Table 5. Reference field of wheat and rice had received FYM annually, but reference soybean after 1985 was turned to green manure as a substitute of FYM.

Table 6 shows values of wheat straw (WS) applied to each section calculated by deducting grain weight from total top weight. WS was the main organic material applied to the soil on

Table 6　Wheat Straw invested from 1980 to 1987 (kg／10a＊)

Section No.	Cropping systems	1980	1981	1982	1983	1984	1985	1986	1987	SUM
10	S－R－S－DC	0	0	0	0	0	992	833	0	1825
2	S－R－S－W－V	0	0	0	0	0	1094	0	0	1094
3	S－R－S－DC	0	0	0	0	0	1012	987	0	1999
4	DC	0	1020	815	732	627	931	934	652	5711
5	DC－R－DC	0	1005	732	0	572	953	0	676	3938
6	W	0	1036	743	793	516	1018	788	905	5799
7	W－R－DC	0	1057	705	0	483	940	868	740	4793
8	W－l．p．R	0	1013	492	835	496	992	0	681	4509
9	W－R－S－F	0	1030	742	0	428	0	1056	0	3256
Ref．W	(Nk)	936	794	743	1333	435	823	925	749	6738

＊ Calculated values (Total top weight - Grain weight)

Table 7　Total Fertilizer Nitrogen, Phosphorus, Potassium, Farm Yard Manure and Wheat straw invested from 1980 to 1987 (kg／10a)

Section No.	Cropping systems	N	P_2O_5	K_2O	FYM	WS	Remarks
		kg/10a					
10	S－R－S－DC	66	100	100	6900	1825	
1	S	16	80	80	10500	0	MC
2	S－R－S－W－V	113	149	145	14900	1094	
3	S－R－S－DC	60	100	100	6900	1999	
4	DC	109	150	150	1500	5711	
5	DC－R－DC	94	130	130	2700	3938	
6	W	65	70	70	0	5799	MC
7	W－R－DC	83	100	100	1200	4793	
8	W－l．p．R	73	110	110	1500	4509	
9	W－R－S－F	92	108	108	0	3256	
Ref.	W (Nk)	42	70	70	8000	6738	Ca 130
	S (N)	18.8	75	81	5400	GM	Ca 130
	R (Sa)	48	96	96	12800	0	Si 960
	R (Kg)	64	96	96	12800	0	Si 960

FYM=Farm yard manure, WS=Wheat straw, GM=Green Manure (Turnip or Oats)
Ca=Calcium Carbonate ($CaCO_3$), Si=Calcium Silicate (Japanese name=Keikaru)

DC systems because the time for crop switching was too short for FYM carriage and dispersion. MC wheat in section No,6 had WS only.

Table 7 summarizes total fertilizer nitrogen, phosphorus, potassium, farm yard manure and wheat straw invested from 1980 to 1987. About 130kg／10a of $CaCO_3$ was applied to the reference upland field, and 120kg／10a of calcium silicate （Japanese name is "Keikaru"） was applied annually to the reference paddy field as soil improving materials.

3. Results and Discussion :

1) Crop Yields among Several Cropping Systems :

Table 8 shows crop yields in each section from 1980 to 1987. All crops are indicated in the column of the harvesting year. Yield measured parts are : grain without chaff or pod for wheat, barley, soybean and rice. Fresh top weight for rye, dentcorn and sudax, and marketable parts for vegetables. Abbreviations of crops and their varieties are shown below the table. Green soybean was cultivated on half of sections No. 4 and 5 in 1987 and shared the sections with soybean. All yields are expressed in kg／10a.

Considering totals, the yields were considerably higher in wheat, soybean and rice, compared with the yields of reference. There were no references in barley, vegetables and forage crops. However, these yields were considerd as high in comparison with standard yields in this region.

Double-cropping system of wheat and soybean in section No. 4 required timely planting but there tended to be a delay in seeding period compared with normal wheat and soybean. However, it showed constantly higher yield than MC of wheat and slightly lower than MC of soybean （Table 8）. This system became possibe in this region due to the introduction of the early maturing soybean variety Wasesuzunari. In this system, soybean cultivation could suppress the weeds in wheat （Takahashi et al., 1985）. Wheat and legume residues incorporated in the soil could maintain soil fertility. All of these factors contributed to raising total land production above that of mono-cropping of each crops. We transferred this DC system technique for extension in Iwate Prefecture in 1983. Furthermore, increments of basal N fertilizer after 1985 （Table 2） resulted in the increase of soybean yields （Table 8）. N-increment was also useful for lengthening the soybean stem to the suitable length to be harvested by machine. Growth time of late planted Wasesuzunari in July tended to be too short for sufficient stem elongation to permit harvesting by machine.

However, double-cropping system of wheat and soybean has two problems. One is the need for timely planting. There is no extra time to change the crops. The increments of basal N also resulted in elongating soybean maturing periods to 2 to 5 days, which made the condition of wheat seeding difficult. It made the condition of soybean seeding more difficult that the changing period from wheat to soybean was during the rainy season （Japanese name: Baiu）. This is the main cause which prevents wide extension of this system in this region.

Another problem is that long-term continuation of this system results in gradual weed and disease damage to crops like that in mono-culture. Although soybean yield on section No.4 increased by increments of N-input after 1985, weeds also increasing yearly, so soybean yields became less than other DC sections （Table 8）.

The former problem can be solved by relay intercropping （Andrews and Kassam, 1976） or

Table 8　Crop yields in each section of field No.2 from 1980 to 1987

Section No.	Crop	Variety year	1980	1981	1982	1983	1984	1985	1986	1987	SUM
			Crops yields (kg/10a)								
10	Wheat	Nk	–	–	–	–	–	458	412	–	870
10	Soybean	W	–	–	–	–	–	256	292	–	548
10	Soybean	N	313	271	–	–	363	–	–	–	947
10	Rice	Sa	–	–	524	563	–	–	–	–	1087
10	Rice	Kg	–	–	–	–	–	–	–	771	771
1	Soybean	N	309	239	261	283	326	311	297	243	2269
2	Wheat	Nk	–	–	–	–	–	453	–	–	453
2	Soybean	N	292	233	–	328	343	–	–	–	1196
2	Rice	Kg	–	–	618	–	–	–	–	723	1341
2	CC	Matsushima	–	–	–	–	–	3070	–	–	3070
2	garlic	Hachimantai	–	–	–	–	–	–	1568	–	1568
2	carrot	Sin-kuroda	–	–	–	–	–	–	4030	–	4030
3	Wheat	N	–	–	–	–	–	473	498	–	971
3	Soybean	W	–	–	–	–	–	293	256	–	549
3	Soybean	N	310	266	294	–	368	–	–	–	1238
3	Rice	Kg	–	–	–	666	–	–	–	753	1419
4	Wheat	Nk	–	485	538	461	431	411	486	391	3203
4	Soybean	W	214*	217	222	273	228	294	262	260	1970
4	G-Soy	Kinshyu	–	–	–	–	–	–	–	651	651
5	Wheat	Nk	–	489	506	–	413	424	–	352	2184
5	Soybean	W	220*	217	222	–	299	343	–	334	1635
5	G-Soy	Kinshyu	–	–	–	–	–	–	–	791	791
5	Rice	Kg	–	–	–	644	–	–	796	–	1440
6	Wheat	Nk	–	487	485	434	368	395	377	420	2966
7	Wheat	Nk	–	480	468	–	372	397	462	468	2647
7	Soybean	W	–	–	–	–	–	366	321	310	997
7	Rice	Kg	–	–	–	662	–	–	–	–	662
8	Wheat	Nk	–	487	351	503	356	393	–	482	2572
8	Soybean	N	316	–	–	–	–	–	422	–	738
8	Rice	Kt	–	427	494	447	–	535	–	553	2456
9	Wheat	Nk	–	493	486	–	325	–	474	–	1778
9	Barley	Benkeimugi	–	–	–	687	–	–	–	–	687
9	Soybean	W	–	–	–	–	331	–	–	–	331
9	Rice	Kt	–	–	–	485	–	–	–	–	485
9	Rice	Kg	–	–	–	–	–	–	–	793	793
9	Rye	Samusashirazu	–	–	–	–	–	3000	–	–	3000
9	Dent	Golddent 1001	–	–	–	–	–	5294	–	–	5294
9	Sudax	Sudac 306	–	–	–	–	–	–	5500	–	5500
Reference	Wheat	Nk	422	346	457	569	320	435	413	512	3474
	Soybean	N	296	263	276	288	357	259	250	306	2295
	Soybean	W	240*	320	330	342	261	272	296	374	2435
	Rice	Sa	614	575	536	465	605	599	609	602	4605
	Rice	Kg	–	–	–	637	673	683	727	665	3385

Abbreviations : CC=Chinese cabbage, G-Soy=Green soybean.

Variety of Wheat; Nk=Nanbukomugi, Soybean; N=Nanbushirome, W=Wasesuzunari (but * is Kokeshijiro)

Rice; Sa=Sasanishiki, Kg=Koganehikari, Kt=Kochiminori.

no-till seeding of wheat and soybean (Baeumer and Bakermans, 1973; Ono et al., 1986). Intercropping of soybean onto the troughs of wheat ridges is laborious but it is an old established technique practiced by small scale farming in this region, while no-till seeding is a new method which is not established yet. We examined fertilization and management methods of non-tillage of soybean cultivation after wheat on alluvial soil (Ono et al., 1986) which confirmed it to be effective. So we transferred the no-till technique in soybean after wheat for extension in Iwate Prefecture in 1986. But this technique is not spreading, and the use of the no-till planter is not yet popular. There seems to be a psychological resistance against accepting the no-till technique, because of a loose field aspect after seeding. However, this is mainly due to smaller scale of upland farming especially of DC system, in this region. No-tillage method is a new conception acceptable to large-scale farmer and also conservative to soil (Baeumer and Bakermans, 1973). So the extension of no-tillage system might accompany farming scale enlargement in the future.

On the other hand, this problem can be solved partially even on a smaller scale by the introduction of earlier harvestable green soybean which is one of the main vegetables of this region. As shown in Table 8, we attempted green soybean cultivation after wheat in sections No. 4 and 5 in 1987. Growth periods of green soybean were shorter than soybean and the yields were good, so seeding of wheat advanced afterwards (Ono et al. 1988b), and yields of wheat also increased. Table 8 also shows the yield of green soybean was superior in section No.5 which was used for paddy in the previous year. We transferred this technique for extension in Iwate Prefecture in 1988. There will be other combination of summer and winter vegetables for the DC system. But cultivatable areas for vegetables are generally small. So this method is restricted to smaller farming only. More essential solution is the no-till seeding mentioned above and also the development of new earlier varieties of wheat and soybean. Earlier varieties also solve the problem of maturing elongation by N-increment.

The latter problem is more difficult because it concerns field ecosystem and pathology. In suppressing of take all root rot diseases of wheat, long-term upland cropping systems are needed (Miyajima, 1985). This DC system is an alternative cropping method and might be susceptible to such diseases. Although wheat and soybean in section No.4 were not affected by diseases, and showed significantly lower densities of weeds than MC sections, weeds like wild spinach, polygonum and chickweed increased. We observed take all root rot diseases on DC wheat planted on volcanic ash soil at Maesawa Town. To suppress such diseases and／or weeds, paddy use for rice cultivation might be effective. Sections No. 3, 5, and 7 were chosen for this purpose. As shown in Table 8, the yield of wheat and soybean after rice cultivation were increased, especially in soybean.

Upland-paddy rotational land use was an established ancient technique especially for southern part of Japan (Miyazaki, 1697) and is considered to be useful to stabilize the DC system even in this region. However, the effects of upland-paddy rotation differed between wheat and soybean (Ono et al. 1988c). Soybean growth and yield were increased immediately after rice, but wheat growth was suppressed in the lst year, and the effects of paddy-rotation appeared after the 2nd cropping year as shown in Table 8. We considered such effective differences between soybean and wheat were caused by the difference in root systems and degree of sensitivity to soil moisture level. This result shows that there will be adequate combination of paddy and upland use interval.

Yields of rice after upland cropping were greater than the continuous cropping of paddy field. Rice growth were greater especially in middle to late stages （Ono et al., 1988a）. The highest rice yield in Table 8 was 796kg／10a of Koganehikari in section No. 5 in 1986. This was the average value of 8 experimental districts of the section, in which we examined several fertilizer levels and the highest yield was 867kg／10a （1085kg／10a in rough rice）. This was done by basal application of N8kg／10a and topdressings of N2kg／10a below 25 days and after 5 days of heading. And other districts also showed higher yields, over 750kg／10 a （Kitada and Ono, 1987）. But such high yields seemed to be supported by the weather condition in 1986 in which temperature was relatively lower in the panicle initiation stage and higher after heading （Table attached 1）. So, the adequate rate of basal nitrogen should be N4kg／10a which was half of the rate of this variety on normal paddy on normal weather condition. This was confirmed by the evidence that the basal N8kg／10a resulted in the collaption of Koganehikari in 1987.

Yields of rice variety Sasanishiki on section No.10 were not so high because of moderate application of fertilizer （basal N2kg／10a） to prevent collaption, but the yield was higher than the reference field of basal N4kg／10a. That Sasanishiki produced higher yield in rotational paddy field than in continuous cropping of paddy was also confirmed at another district, Maesawa Town, which had volcanic ash soil （Ono et al., 1986）. The duration of higher yielding of Sasanishiki in rotational paddy field could be confirmed until 3 years after rotation at Maesawa Town.

Such rotational land use could produce higher rice yield with less fertilizer than normal paddy fields. Hereafter, the policy of paddy use restriction is expected to produce larger areas of upland-paddy rotational land use. Rice variety Koganehikari was adequate for such rotational paddy fields but inferior in taste and price to Sasanishiki. Development of new rice varieties which have as good a taste as Sasanishiki, and high resistance to collaption as Koganehikari, are needed for such upland-paddy rotational land use. We are now expecting to introduce the new rice variety Chiyohonami which was developed by Furukawa Agri. Exp. Stn. and intend to promote it as an encouragement variety in lwate Prefecture in 1989.

Wheat and late-planted rice double-cropping system was possible in section No.8 using earliest rice variety Kochiminori （Table 8）. The cultivation method of late-planted rice after wheat was reported previously, using the data of 1981 （Shinke et al. 1982） and it was also transferred for the extension in Iwate Prefecture in 1983. This system, however, had a problem of rice growth suppression in southern Honshu. This might be caused by abnormal reduction of soil condition which produces harmful organic acids because of the incorporated wheat straw and the higher temperature in southern Honshu （Suzuki, 1985）. Such problem did not occur on section No.8 possibly because of the lower temperature in this region. However, it was observed that carrying off the wheat straw suppressed topsoil reduction and also blast diseases, and the yield of rice also increased. Nevertheless, yields of each crop in this system were lower than in other sections. This might be due to the suppression of wheat growth immediately after rice as mentioned above and because the time is too short even for Kochiminori. Kochiminori was also poor in taste. To make this system more applicable, development of earlier, better-tasting rice varieties are needed. But the policy of the restriction of paddy use for rice production has resulted in governmental subsidies to the farmer who uses paddy field for upland crops. Therefore, in this system, subsidy could not be paid to farmers.

Table 9 re-arranges the yields of wheat and soybean from Table 8. Yield average of wheat in most sections were larger than reference field except sections No. 6 and 8 (Table 9). Section No. 6 was MC wheat and section No. 8 was DC wheat with late-planted rice. Average yields of soybean variety Nanbushirome were higher than reference field, but Wasesuzunari was lower except for sections No. 7 and 9. Worthy of special mention is that late-planted soybean Wasesuzunari exceeded in yields normal planted Nanbushirome after 1985. This shows that upland and paddy rotational land use might be superior to using only upland crops rotation.

Table 10 shows yearly comparison of the yields of wheat and soybean in each section, with the reference yield (Index values were calculated with the reference yield as 100). And

Table 9 Arrangement of the yields of Wheat and Soybean (kg/10a)

Section No.	Cropping systems	Variety	1980	1981	1982	1983	1984	1985	1986	1987	Pure Avg	Index
Reference	Wheat		422	346	457	569	320	435	413	512	434	100
2	S-R-S-W-V	Nk						453			453	104
3	S-R-S-DC	Nk						473	498		486	112
4	DC	Nk		485	538	461	431	411	486	391	458	106
5	DC-R-DC	Nk		489	506		413	424		352	437	101
6	W	Nk		487	485	434	368	395	377	420	424	98
7	W-R-DC	Nk		480	468		372	397	462	468	441	102
8	W-l.p.R	Nk		487	351	503	356	393		482	429	99
9	W-R-S-F	Nk		493	486		325		474		445	103
10	S-R-S-DC	Nk						458	412		435	100
Reference	Soybean	N	296	263	276	288	357	259	250	306	287	100
1	S	N	309	239	261	283	326	311	297	243	284	99
2	S-R-S-W-V	N	292	233		328	343				299	104
3	S-R-S-DC	N	310	266	294		368				310	108
8	W-l.p.R	N	316						422		369	129
10	S-R-S-DC	N	313	271			363				316	110
Reference	Soybean	W	240*	320	330	342	261	272	296	374	304	100
3	S-R-S-DC	W						293	256		275	90
4	DC	W	214*	217	222	273	228	294	262	260	246	81
5	DC-R-DC	W	220*	217	222		299	343		334	273	90
7	W-R-DC	W						366	321	310	332	109
9	W-R-S-F	W					331				331	109
10	S-R-S-DC	W						256	292		274	90

Reference Wheat and Soybean are cultivated after green manure in other upland rotational fields. Section No. and abbreviation is same as Table 1. Varieties: Nk is Nanbukomugi (wheat), N is Nanbushirome (soybean), W is Wasesuzunari (soybean for double cropping), but* is Kokeshijiro

Table 10 Comparison of the yield of Wheat and Soybean in each section with the reference yield between 1982 to 1987 (Index values: Reference=100)

Section No.	Cropping systems	Variety	1980	1981	1982	1983	1984	1985	1986	1987	Pure average
Reference	Wheat	Nk	100	100	100	100	100	100	100	100	100
2	S-R-S-W-V	Nk						104			104
3	S-R-S-DC	Nk						109	121		115
4	DC	Nk		140	118	81	135	94	118	76	109
5	DC-R-DC	Nk		141	111		129	97		69	109
6	W	Nk		141	106	76	115	91	91	82	100
7	W-R-DC	Nk		139	102		116	91	112	91	109
8	W-l.p.R	Nk		141	77	88	111	90		94	100
9	W-R-S-F	Nk		142	106		102		115		116
10	S-R-S-DC	Nk						105	100		103
Reference	Soybean	N	100	100	100	100	100	100	100	100	100
1	S	N	104	91	96	98	91	120	119	79	101
2	S-R-S-W-V	N	99	89		114	96				101
3	S-R-S-DC	N	105	101	107		103				103
8	W-l.p.R	N	107						169		138
10	S-R-S-DC	N	106	103			102				103
Reference	Soybean	W	100*	100	100	100	100	100	100	100	100
3	S-R-S-DC	W						108	86		97
4	DC	W	89*	68	67	80	87	108	89	70	82
5	DC-R-DC	W	92*	68	67		115	126		89	93
7	W-R-DC	W						135	108	83	109
9	W-R-S-F	W					127				127
10	S-R-S-DC	W						94	99		96

Abbreviations are same as Tabl 9

Table 11 Comparison of the yield of rice in each section with the reference yield between 1982 to 1987 (Index values: Reference=100)

Section No.	Cropping systems	Variety	1982	1983	1984	1985	1986	1987	pure average
Reference	rice	Kg	–	100	–	–	100	100	100
2	S-R-S-W-V	Kg	–	–	–	–	–	109	109
3	S-R-S-DC	Kg	–	105	–	–	–	113	109
5	DC-R-DC	Kg	–	101	–	–	119	–	110
7	W-R-DC	Kg	–	104	–	–	–	–	104
9	W-R-S-F	Kg	–	–	–	–	–	119	119
10	S-R-S-DC	Kg	–	–	–	–	–	116	116
Reference	rice	Sa	100	100	–	–	–	–	100
10	S-R-S-DC	Sa	98	121	–	–	–	–	109

Table 11 shows the same comparison for rice. Yield index of MC wheat (section No. 6) showed a tendency of yearly decrease but MC soybean (section No. 1) did not show such a trend. Indexes of wheat were significantly lower in 1983 and 1987; however, reference yields for these years were extremely high (Table 9). Yearly difference of the wheat yield was greater in reference upland rotational field.

MC soybean (N) significantly increased in yield with introduction of rice as shown in the difference between section No.1 and 2, 3, 10 in 1983 and 1984. MC wheat did not show such an effect. Effect of rice introduction showed the same tendency to DC soybean (W) and wheat as shown in the section No.4, 5 and 7 after 1984. However, wheat yields increased but soybean yields decreased yearly, after rice introduction as shown in Table 8. Considering the above data, adequate interval of upland use on paddy field seemed to be 3 to 4 years. On the other hand, adequate interval of paddy-rice cultivation seemed to be 3 years, as mentioned above. However, interval of rice cultivation was greatly affected by the policy decision.

2) Total Weight and Harvest Index of Wheat and Soybean :

Table 12 shows total weight of the top of wheat and soybean. Average values showed total weight of wheat was larger in sections No. 2, 3, 10 and smaller in sections No. 5, 6, 7, 8, 9 than the reference wheat. The former sections were invested with larger amounts of FYM than the latter (Table 5 and 7) which meant the effect of FYM on the improvement of total growth on wheat was positive. The lowest total weight is observed in section No. 8, which meant that the suppression of wheat yield immediately after rice cultivation was due to the decrease of total growth.

Section No.1 was continuous MC soybean for 8 years. Sections No.2 and 3 were soybeans mono-cropped between 1980 to 1981 and 1982, respectively (Table 1). Both soybeans showed rapid decrease in total weight by the continuation of mono-cropping when compared with the reference. This showed the first effect of soybean mono-cropping was the depression of total growth. After paddy introduction, declines in total weight recovered as shown in sections No. 2 and 3 (Table 12). Total weights of soybean variety Wasesuzunari were smaller than reference because of shorter growth period. However, the degree of diminution of total weight (Table 12) was larger than the difference of seed yield (Table 9). This result suggests an increase of Harvest Index (HI) of DC soybean.

Raising the HI is most useful to agriculture, however it has been regarded as remaining stable within each soybean variety (Spaeth et al., 1984). Shimono (1986) also concluded the HI of wheat was due to genetic characteristics which could be amended by improvement of varieties. He mentioned that the effects of cultivation and／or fertilization on HI were relatively small.

Table 13 shows the Harvest Index (HI) of wheat and soybeans in each cropping system which were calculated from Tables 9 and 12. Pure average of HI tended to be higher in DC wheat than the reference wheat as shown in sections No. 4, 5, 7, and 8. HI of MC wheat in section No.6 was similar to the reference. Delay of the seeding period about 1 or 2 weeks more than normal wheat seemed to be the cause of HI increase in DC wheat. However, the difference in HI between upland wheat and rotational wheat was small.

Table 12 Total Top Weight (kg／10a) of Wheat and Soybean

Section No.	Cropping systems	Variety	1980	1981	1982	1983	1984	1985	1986	1987	Pure Avg	Index
Reference	Wheat		1358	1140	1200	1902	755	1258	1338	1261	1277	100
2	S-R-S-W-V	Nk						1547			1547	121
3	S-R-S-DC	Nk						1485	1485		1485	116
4	DC	Nk		1505	1353	1193	1058	1342	1420	1043	1273	100
5	DC-R-DC	Nk		1494	1238		985	1377		1028	1224	96
6	W	Nk		1523	1228	1227	884	1413	1165	1325	1252	98
7	W-R-DC	Nk		1537	1173		855	1337	1330	1208	1240	97
8	W-l .p.R	Nk		1500	843	1338	852	1385		1163	1180	92
9	W-R-S-F	Nk		1523	1228		753		1530		1259	99
10	S-R-S-DC	Nk						1450	1245		1348	106
Reference	Soybean	N	815	807	743	730	985	871	839	710	813	100
1	S	N	808	680	568	625	798	810	758	507	694	85
2	S-R-S-W-V	N	764	663		715	851				748	92
3	S-R-S-DC	N	800	748	601		939				772	95
8	W-l .p.R	N	790						990		890	109
10	S-R-S-DC	N	817	813			958				863	106
Reference	Soybean	W	645*	639	639	669	445	679	647	629	624	100
3	S-R-S-DC	W						521	467		494	79
4	DC	W	628*	460	398	491	430	519	493	431	481	77
5	DC-R-DC	W	671*	506	402		541	600		569	548	88
7	W-R-DC	W						655	619	549	608	97
9	W-R-S-F	W					644				644	103
10	S-R-S-DC	W						446	540		493	79

Abbreviations are same as Tabl 9

HI of soybean variety Wasesuzunari was higher than Nanbushirome which indicated varietal improvement. However, all of late-planted Wasesuzunari in the sections showed higher HI than the reference Wasesuzunari. Effect of paddy rotation on HI was small. HI of soybean variety Nanbushirome showed highest value in MC in section No.1. And the difference in HI between reference field and section No. 1 expanded yearly. This result suggests that mono-cropping of soybean suppressed total weight first. Such a tendency was observed also in continuous double-cropped soybean Wasesuzunari in section No. 4.

These results suggest that HI was influenced by seeding time, meaning growth period , and not by upland-paddy land use, which had the same effect on both seed yield and total growth. Effects of mono-cropping differed in wheat and soybean. Wheat did not change but soybean increased in HI by MC on the alluvial soil.

3) Economic Estimation of Each Cropping System :

The above data concerning cropping systems, land use and management of materials and labor, require precise economical analysis. But we did not grasp the precise economical data through

Table 13 Harvest Index (% of Yield/Total top weight) of Wheat and Soybean

Section No.	Cropping systems	Variety	1980	1981	1982	1983	1984	1985	1986	1987	Pure Avg	Index
Reference	Wheat	Nk	31.1	30.4	38.1	29.9	42.4	34.6	30.9	40.6	34.7	100
2	S-R-S-W-V	Nk						29.3			29.3	84
3	S-R-S-DC	Nk						31.9	33.5		32.7	94
4	DC	Nk		32.2	39.8	38.6	40.7	30.6	34.2	37.5	36.2	104
5	DC-R-DC	Nk		32.7	40.9		41.9	30.8		34.2	36.1	104
6	W	Nk		32.0	39.5	35.4	41.6	28.0	32.4	31.7	34.4	99
7	W-R-DC	Nk		31.2	39.9		43.5	29.7	34.7	38.7	36.3	105
8	W-l.p.R	Nk		32.5	41.6	37.6	41.8	28.4		41.4	37.2	107
9	W-R-S-F	Nk					43.2		31.0		37.1	107
10	S-R-S-DC	Nk						31.6	33.1		32.3	93
Reference	Soybean	N	36.3	32.6	37.1	39.5	36.2	29.7	29.8	43.1	35.5	100
1	S	N	38.2	35.1	46.0	45.3	40.9	38.4	39.2	47.9	41.4	117
2	S-R-S-W-V	N	38.2	35.1		45.9	40.3				39.9	112
3	S-R-S-DC	N	38.8	35.6	48.9		39.2				40.6	114
8	W-l.p.R	N	40.0						42.6		41.3	116
10	S-R-S-DC	N	38.3	33.3			37.9				36.5	103
Reference	Soybean	W	37.2*	50.1	51.6	51.1	58.7	40.1	45.7	59.5	51.0	100
3	S-R-S-DC	W						56.2	54.8		55.5	109
4	DC	W	34.1*	47.2	55.8	55.6	53.0	56.6	53.1	60.3	54.5	107
5	DC-R-DC	W	32.8*	42.9	55.2		55.3	57.2		58.7	53.8	105
7	W-R-DC	W						55.9	51.9	56.5	54.7	107
9	W-R-S-F	W					51.4				51.4	101
10	S-R-S-DC	W						57.4	54.1		55.7	109

Abbreviations are same as Tabl 9

this experiment, so we conducted suppositional analysis using three conditions.

As the first condition, we excluded sections No. 2 and 9 which contained various vegetables and forage crops, for such crops had fluctuating market and could not be priced easily. So we used only wheat, soybean and rice. As for the second condition, unit prices and costs for each crop were assumed to be stable at the final year's value between 1980 to 1987. And as the third condition, we dealt with each section as a total system in spite of the changing of systems in 1984. So the total gains in each section were calculated by the summation of multiplication between unit prices in 1987 and yields of each crop. Total cost was calculated by the same procedure.

Table 14 shows unit prices of each crop in highest grade, in 1987. Unit prices of wheat and rice were decided by policy as in the note below the table, however, the final price of Sasanishiki differed with each prefecture and district. We were notified about the 1987 unit price of Sasanishiki by Esashi Agricultural Cooperative. Final price of soybean was also complicated and we were notified about it by Hanamaki Agricultural Cooperative.

Table 15 shows basic cost data of each crop (yen/10a) in 1987 which appeared in Agricultural

Table 14　Unit Price of each Crop in 1987

Crop	Variety	yen／kg	Remarks
Wheat	Nanbukomugi	173.8	NT 928 *
Soybean	Nanbushirome	276.4	by Hanamaki Agricultural Cooperative
	Wasesuzunari	276.4	same as above
Rice	Sasanishiki	370.6	by Esashi Agricultural Cooperative
	Koganehikari	290.1	NT 928 *

* Notification No. 928 of the Ministry of Agr., Forestry and Fishery (1987)

Table 15　Cost Data (yen／10a) at 1987 by Iwate Statistical Soc. of Agr. and Forestry (1988)

Crop	T-Cost	LCF	Cost 1	Cost 2	Cost 3	Remarks
Wheat	52154	12229	39925	49807	66229	All Japan
Soybean	64390	32845	31545	64241	85768	All Japan
Rice	148835	48752	100083	142071	184673	Iwate Prefecture

T-Cost=Total cost,　　LCF=Labour Cost for Family,

Cost 1 = Total cost − LCF

Cost 2 = Total cost − (a by-product price),

Cost 3 = Cost 2 + (capital interest) + (ground rent)

Statistics (Iwate Statistical Soc. of Agr. and Forestry 1988). We used the cost data for the whole country for wheat and soybean, but used prefectural data for rice. Total cost is the summation of total input which included the cost of seeds, fertilizers, herbicides, fuel, water, buildings, machines and labor. LCF is Labor Cost for Family within the total cost. Cost 1 is total cost minus LCF. Cost 2 is total cost minus by-product price (rice straw for marketing, etc.). Cost 3 is Cost 2 + Capital interest + ground rent. Total gain was calculated by multiplication of unit prices of 1987 and total yield of each crops from 1980 to 1987, then divided by 8.

Table 16 showed the method of calculation of Gain 1 calculated by subtraction of Cost 1 from total gain. other gains were calculated by the same procedure (using Lotus 1−2−3). Table 17 shows the comparison of total gain, 3 costs and 3 gains for each section.

Table 17 shows that mono-cropping of Sasanishiki was highest of all gains and Koganehikari was the second in Gains 1 and 2. The results suggest the superiority of rice-monoculture in the Japanese price system. However, for that very reason, the government has made subsidies for wheat and soybean cultivated in paddy fields. Excepting MC rice, wheat-soybean double-cropping system is higher than each monoculture in Gains 1 and 2. Paddy-rice introduction to the DC system is also effective in Gains 1 and 2 as shown in the differences between sections No. 4 and 3, 5, 7 and 10. Mono-cropping of soybean was lowest in Gains 1 and 2 mainly due to the shortages of total land productivity and relatively higher cost. Gain 3 was lowest in wheat- late planted rice DC system on section No. 8 which was due to lower yields and significantly higher cost of rice production.

Table 16 Gain 1 of each section calculated by subtraction of Cost 1 from T-Gain

Sect No.	Crops	Var	YD 1 avg	FRQ	YD 2 kg/8y	YD2xUP ¥/8y	Sum ¥/sect	T-Gain ¥/y	FRQxC1 ¥/8y	Sum ¥/sect	Cost 1 ¥/y	Cain 1 ¥/y
10	Wheat	Nk	435	2	870	151206			79850			
10	soy	W	274	2	548	151467			63090			
10	soy	N	316	3	947	261751			94635			
10	rice	Sa	544	2	1087	402842			200166			
10	rice	Kg	771	1	771	223667	1190933	148867	100083	537824	67228	81639
1	soy	N	284	8	2269	627152	627152	78394	252360	252360	31545	46849
3	Wheat	Nk	486	2	971	168760			79850			
3	soy	W	275	2	549	151744			63090			
3	soy	N	310	4	1240	342736			126180			
3	rice	Kg	710	2	1419	411652	1074891	134361	200166	469286	58661	75701
4	Wheat	Nk	458	7	3203	556681			279475			
4	soy	W	246	8	1968	543955	1100637	137580	252360	531835	66479	71100
5	Wheat	Nk	437	5	2184	379579			199625			
5	soy	W	273	6	1638	452743			189270			
5	rice	Kg	720	2	1440	417744	1250066	156258	200166	589061	73633	82626
6	Wheat	Nk	424	8	3390	589132	589132	73642	319400	319400	39925	33717
7	Wheat	Nk	441	7	3088	536723			279475			
7	soy	W	332	3	997	275571			94635			
7	rice	Kg	662	1	662	192046	1004340	125543	100083	474193	59274	66268
8	Wheat	Nk	429	6	2572	447014			239550			
8	soy	N	369	2	738	203983			63090			
8	rice	Kt	491	5	2456	712486	1363482	170430	500415	803055	100382	70053
Ref.	Wheat	Nk	434	8	3474	603781	603781	75473	319400	319400	39925	35548
	soy	N	287	8	2295	634338	634338	79292	252360	252360	31545	47747
	soy	W	304	8	2435	673034	673034	84129	252360	252360	31545	52584
	rice	Sa	576	8	4605	1706613	1706613	213327	800664	800664	100083	113244
	rice	Kg	677	8	5416	1571182	1571182	196398	800664	800664	100083	96315

Sect=Section, Var=Crop Varieties,

YD 1=average yield of each crops in each section

FRQ=Frequency of each crops from 1980 to 1987

YD 2=YD1xFRQ

UP=Unit Price (Table 14),

C1=Cost 1 (Table 15)

Sum=Summation of gain or cost in each section for 8 years

Government subsidies are calculated by the summation of basal cost, field scale and cooperative addition by the forms of farming groups. We used ¥51,000／10a which was composed of ¥21,000 basal cost, ¥20,000 scale addition, and ¥10,000 cooperative addition. This is a real value paid to a large farming group in the vicinity of KN Branch in 1988 and was confirmed by

Table 17 Comparison of 3 Gains by the Subtraction of Costs 1,2,3 on each section

Section No.	Cropping System	Yield AVG	T-Gain ¥/year	Cost 1	Cost 2	Cost 3	Gain 1	Gain 2	Gain 3
				………… ¥/year/10a …………			………… ¥/year/10a …………		
10	S-R-S-DC		148867	67228	105879	139415	81639	42988	9452
1	S	284	78394	31545	64241	85768	46849	14153	-7374
3	S-R-S-DC		134361	58661	96150	127052	75701	38211	7310
4	DC		137580	66479	107822	143718	71100	29757	-6139
5	DC-R-DC		156258	73633	114828	151887	82626	41430	4371
6	W	424	73642	39925	49807	66229	33717	23835	7413
7	W-R-DC		125543	59274	85430	113198	66268	40112	12345
8	W-l.p.R		170435	100382	142210	186534	70053	28225	-16099
Referenc	Wheat (Nk)	434	75473	39925	49807	66229	35548	25666	9244
	soybean (N)	287	79292	31545	64241	85768	47747	15051	-6476
	soybean (W)	304	84129	31545	64241	85768	52584	19888	-1639
	rice (Sa)	576	213327	100083	142071	184673	113244	71256	28654
	rice (Kg)	677	196398	100083	142071	184673	96315	54327	11725

Table 18 Comparison of 3 Gains after addition of encouragement money

Sect No.	Cropping System	FRQ Upland	Encouragement Money	Gain 1E	Gain 2E	Gain 3E
				……………… ¥/year/10a ………………		
10	S-R-S-DC	7	44,625	127,264	87,613	54,077
1	S	8	51,000	97,849	65,153	43,626
3	S-R-S-DC	6	38,250	113,951	76,461	45,560
4	DC	8	51,000	122,100	80,757	44,861
5	DC-R-DC	6	38,250	120,876	79,680	42,621
6	W	8	51,000	84,717	74,835	58,413
7	W-R-DC	7	44,625	110,893	84,737	56,970
8	W-l.p.R	2	12,750	82,803	40,975	3,349
Ref.	wheat (Nk)	8	51,000	86,548	76,666	60,244
	soybean (N)	8	51,000	98,747	66,051	44,524
	soybean (W)	8	51,000	103,584	70,888	49,361
	rice (Sa)	0	0	113,244	71,256	28,654
	rice (Kg)	0	0	96,315	54,327	11,725

FRQ=Frequency of upland cropping year from 1980 to 1987

Encoragment money=FRQ x 51,000/8

Gains 1E, 2E and 3E=Gains 1, 2 and 3 + Encouragement money

Mizusawa Agricultural Extension Office and Iwate Prefectural Office.

Table 18 showed the comparison of 3 gains after addition of these subsidies which was calculated from the frequency of upland cropping year and expressed as Gain 1E, 2E, and 3E. In Table 18, reference upland crops were supposed to be cultivated on paddy fields. Gains 1E, 2E, 3E became higher than Gains 1, 2, 3 in the upland cropping sections which also exceeded rice monoculture, under these experimental yield levels.

Gain 1E is supposing the LCF as a gain and this is most widely used in economical analyses in Iwate Prefecture. Gain 1E was lower in MC and higher in wheat-soybean DC systems, which has the same tendency of Gain 1. But lowest in wheat-late planted rice DC system because of the shortages of subsidies. Sections which contained wheat and soybean DC system showed the same or higher gains than MC Sasanishiki. But the differences on these sections were small, which meant upland-paddy rotational land use did not result in the increase of Gain 1E, which was also due to the shortages of subsidies.

Gain 2E only subtracts by-product prices from total cost in which LCF was regarded as a cost. Gain 2E showed the same tendency as Gain 1E. However, the advantages of DC systems compared with MC soybean and wheat became smaller than Gain 1E. This result shows that the higher gains from the introduction of soybean-wheat double-cropping system are owed largely to family labor.

Gain 3E contains not only total cost but also capital interest and ground rent which was needed by the larger-scale farmer. Differences of Gain 3E in each section were small but mono-cropping of wheat was highest. This is mainly due to the lower cost of wheat production (Table 15) and seemed to be the reason why wheat on paddy fields tended to be mono-cropped in most areas. Cost 3 might not be applicable to the calculation of cost which included DC system, because capital interest and ground rent were calculated for one crop／year.

Nevertheless, development of the methods for lowering cost of each crop production is needed, especially for scale-enlargement. Lowering the cost should be done both managementally and technologically for the duration of high productivity by multiple cropping. The no-tillage system for wheat, soybean and rice seem to be one of the reasons for the lowering of the cost for fuel, machine and labor. Such options require more research and extension for making a sustainable future agriculture (Francis et al., 1987).

4. Snmmary

Eight years of research work were conducted to determine adequate cropping systems on the alluvial paddy field in the southern region of Iwate Prefecture, Japan. The systems were arranged for the high and durable production not only of upland crops but also paddy rice after upland croppings.

The wheat and soybean double-cropping (DC) system required timely planting; however, it increased total land production which included higher yield of wheat and about same yield of soybean as in monoculture. But long-term continuation of the system resulted in decrease of yield productivity because of weeds and diseases mainly due to the short-term alternating croppings. Paddy use for rice cultivation reduced these problems and increased the yields not only of upland crops but also of paddy rice. So upland-paddy rotational land use was useful for stabilizing the DC system. However, effects of paddy rotation differed in wheat and soybean. This suggests there might be a successful combination of paddy and upland use interval. We estimated the upland interval on paddy field to be about 3 to 4 years.

Economic analysis showed the superiority of DC system and the introduction of paddy-rice cultivation, but it was owed greatly to family labor of the farmer and is suitable for small-farming now. Enlargement of the farming scale requires further lowering of the cost of

production , both managementally and technologically, for the duration of high productivity by the DC system.

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Table attached 1　Average Tamperature (℃) in KN Branch

year	month 1	2	3	4	5	6	7	8	9	10	11	12	AVG
1980	-1.3	-3.2	2.3	8.2	15.7	21.3	20.6	20.9	19.4	13.0	7.6	0.7	10.4
1981	-3.5	-1.1	2.6	9.3	13.0	17.3	24.4	23.6	17.9	12.6	4.3	1.5	10.2
1982	-0.7	-1.5	3.6	9.2	16.2	18.3	21.4	24.5	18.9	13.8	7.0	3.3	11.2
1983	-0.3	-1.7	2.6	11.7	15.6	17.3	20.6	24.8	20.5	12.2	6.0	-0.7	10.7
1984	-4.7	-3.6	-1.0	7.2	14.2	20.0	24.1	26.5	19.2	11.6	5.6	0.7	10.0
1985	-4.5	-0.4	2.4	10.2	15.5	17.9	23.6	27.1	19.6	12.9	6.8	0.3	11.0
1986	-2.9	-3.6	2.3	9.3	14.4	19.0	20.9	25.0	20.7	11.2	5.3	2.7	10.4
1987	-2.0	0.2	3.2	8.4	15.3	20.1	23.3	23.8	20.1	13.9	6.6	1.6	11.2
AVG	-2.5	-1.9	2.3	9.2	15.0	18.9	22.4	24.5	19.5	12.7	6.2	1.3	10.6

Table attached 2　Precipitation (mm) in KN Branch

year	month 1	2	3	4	5	6	7	8	9	10	11	12	sigma
1980	65	62	77	110	130	104	286	223	49	185	44	94	1428
1981	65	63	50	121	131	230	149	315	109	194	52	66	1544
1982	46	45	79	143	114	130	113	123	140	78	125	64	1200
1983	57	38	89	93	76	137	256	117	188	105	79	41	1275
1984	77	89	62	102	105	85	143	74	163	95	32	52	1078
1985	53	52	70	96	95	158	115	55	168	63	156	30	1110
1986	52	38	37	92	74	164	134	165	69	109	82	61	1076
1987	70	32	85	19	115	45	144	338	111	30	64	33	1083
AVG	60	52	69	97	105	132	167	176	125	107	79	55	1224

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岩手県南部沖積水田での各種作付体系における収量比較

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＜要　旨＞

岩手県南部の沖積水田における適切な作付体系を見い出すため，8年間の試験が行われた．この体系は高収と長期的持続生産をめざして設計されたものであり，畑作物のみならず復元田水稲栽培も含む．

小麦と大豆の1年2作体系は適時播種が要求されるが，全体の土地生産を向上させた。これは各々の連作よりも高い小麦収量とほぼ同程度の大豆収量の組合せによる．しかしこの体系を長期間継続すると，短期間の交互作のため雑草や病害により収量生産性が低下した．水稲生産のための水田利用はこれらの問題を減少し，畑作物のみならず水稲の収量も増大させた．そのため田畑輪換の土地利用はこの1年2作体系を安定化させるために有効であった．しかし田畑輪換の効果は小麦と大豆で異なった．このことは水田と畑利用期間の適正な組合せがあることを示している．我々は水田における適正畑利用期間を約3～4年と推定した．

1年2作体系や田畑輪換の組合せは経営的にも優れていたが，主にそれは家族労働に依存しており，小規模経営に適している．2作体系による高生産性を規模拡大した場合も持続させるためには，経営的にも技術的にも更に生産費を下げることが要求される．

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