International specialized media for agricultural mechanization in Asian developing countries.

AMA

AGRICULTURAL MECHANIZATION IN ASIA

VOL. IV, NO. 1, SPRING 1973

Multiple-Cropping and Mechanization

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

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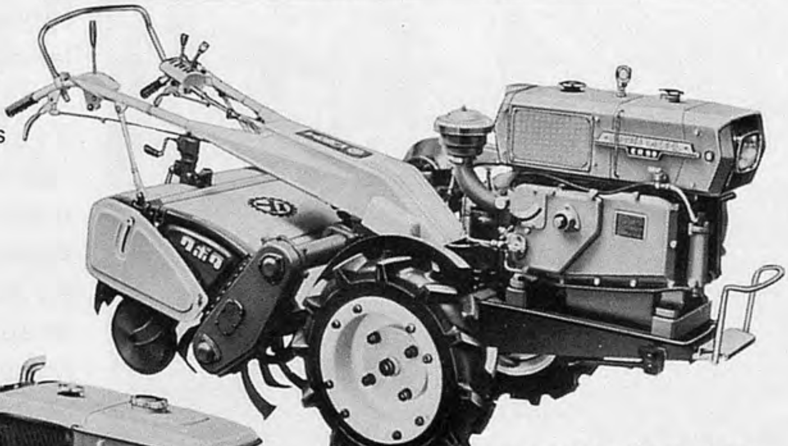
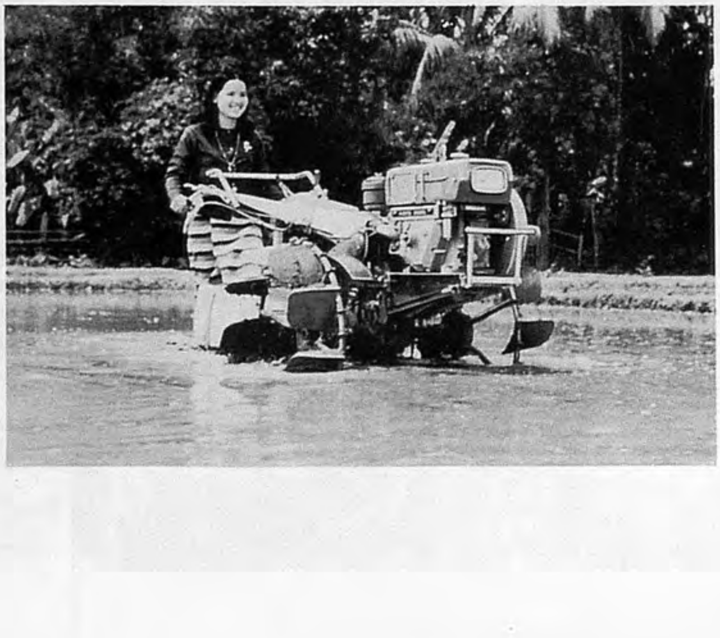
K550	ER50-2	5-6.5HP/ 2,200rpm	Forward 6 Reverse 2	480–600mm	14 pcs.
K700	ER65-2	6.5-8HP/ 2,200rpm	Forward 6 Reverse 2	510–600mm	18 pcs.
KF	KND70	7-9HP/ 1,600rpm	Forward 4 Reverse 1	480–750mm	14 pcs.
	KNDR70L	7-9HP/ 1,600rpm			
KMB200	KND90	9-12HP/ 2,000rpm	Forward 6 Reverse 2	600mm	20 pcs.
	KNDR90	9-12HP/ 2,000rpm			



Model KMB-200

Model K-700



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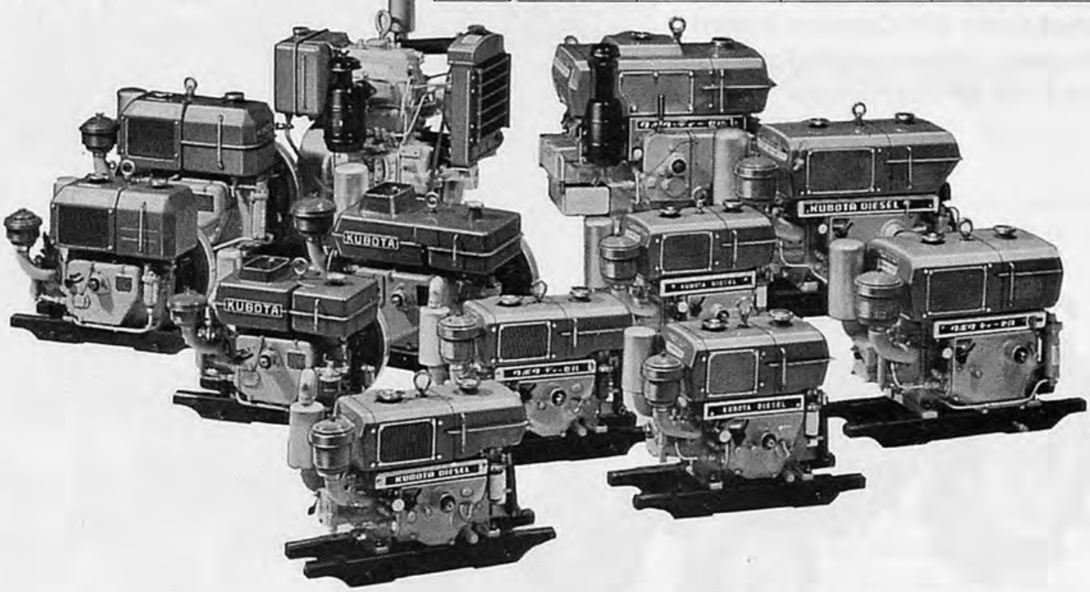
	KND 40	4~5HP	2,000	65 kg/143 Lbs
	KND 5B	5~6.5HP	2,200	75 kg/165 Lbs
	KND 70	7~9HP	1,600	112 kg/246 Lbs
	KND 90	9~12HP	2,000	135 kg/297 Lbs
	KNDR 70L	7~9HP	1,600	100 kg/219 Lbs
	KNDR 90	9~12HP	2,000	145 kg/318 Lbs
RADIATOR COOLING	ER 30	3~3.5HP	2,000	55 kg/121 Lbs
	ER 40	4~5HP	2,000	60 kg/132 Lbs
	ER 50	5~6.5HP	2,200	65 kg/143 Lbs
	ER 65	6.5~8HP	2,200	75 kg/165 Lbs
	ER 75	7.5~9HP	1,800	108 kg/238 Lbs
	ER 90	9~12HP	2,000	145 kg/319 Lbs
	ER 100	10~13HP	1,800	153 kg/337 Lbs
	ER 150N	15~18NP	1,800	247 kg/543 Lbs
	UH 3A	15~18HP	1,800	265 kg/583 Lbs



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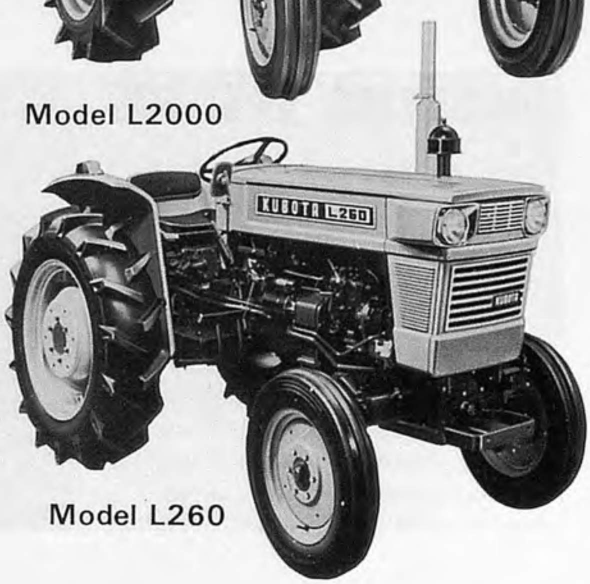
Model	Engine output	Ground clearance	PTO rpm	Weight
L1500	15 HP	330 mm	597/850/ 1,185/1,371	638 kg/1,400 lbs.
L2000	20 HP	350 mm	576/820/ 1,140/1,430	695 kg/1,529 lbs.
L260	26 HP	370 mm	541/696/ 984/1,266	1,000 kg/2,205 lbs.
L350	35 HP	484 mm	565/1,062	1,440 kg/3,170 lbs.

Model L1500

Model L2000

Model L350



Model L260

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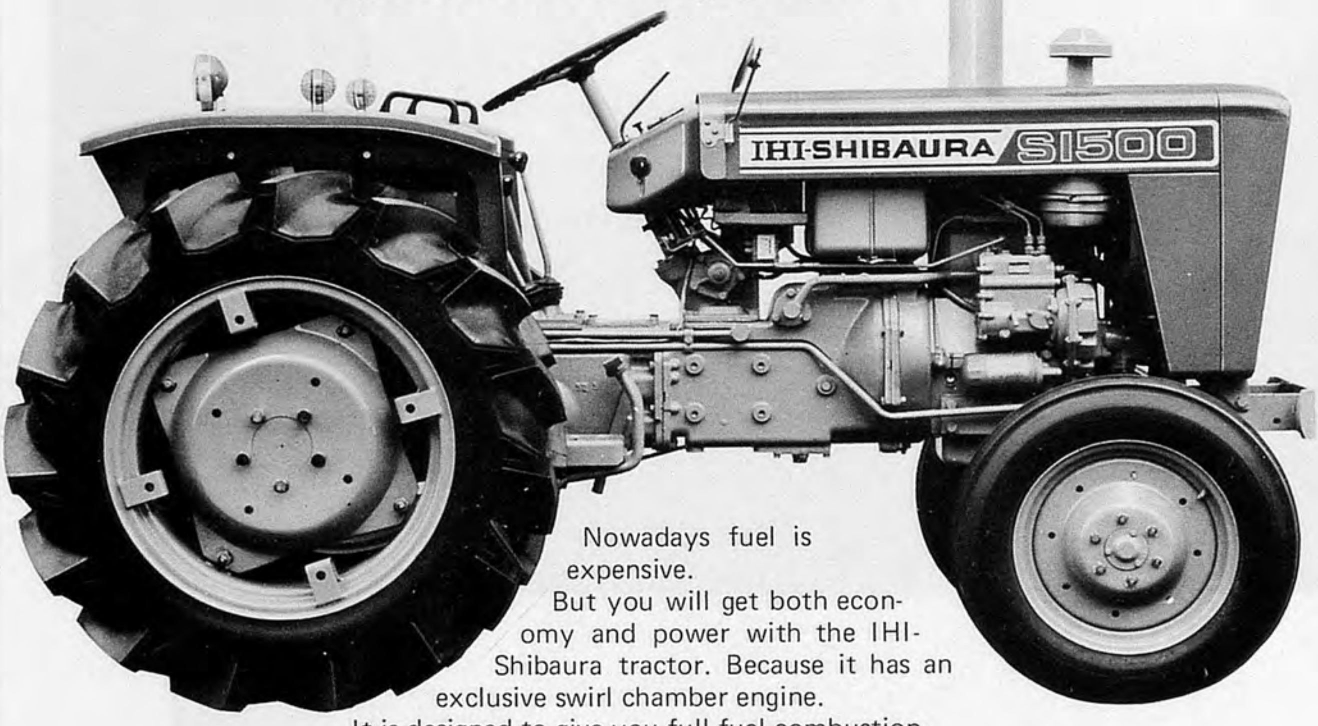

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AMA

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Preface

We had to again realize how difficult to increase enough food production catching up with the rapid population growth in the world after 1970, when many people thought that they could at last overcome the food-population problems with modern technology.

Even among developed countries, the number of rich countries in food are very limited as we observed in 1972. Especially in Asian countries, we have to jump up food production with the limited farming land, which average space per a farmer is decreasing. How can we produce enough food in these highly populated area, solving unemployment problem at the same time?

We need methods to increase land productivity and labor requirement. Multiple-cropping method is one of the splendid answers. There are still remained much work which should be done for spreading this multiple cropping method.

Water and timely operations are essential for this. The mechanization will overcome peak labor for timely operations, which will be more complicated than in single cropping. Farmers need a set of various kind of implements to mechanize the multiple cropping. The research and development work for this are still behind. The total design of required operations and the set of machinery and implements are especially needed for each of cropping patterns. The optimization of the total design would need more sophisticated approach such as systems engineering.

The positive action of local manufacturers are needed to design these various kinds of implements. Needed consulting work for these local manufacturers would show great effect to promote widely spreading multiple cropping.

As to Water management, there are also many difficulties both of the countries of the flooded and the countries of the dry. As Multiple cropping and its mechanization is essential for solving food problems, we publish this issue. This theme is so important and have to cover so many subjects. Then we are planning to publish the next issue of AMA also under the same theme.

Lastly I would like to say sincere thanks to all the contributers and gladly introduce you new co-editors from Bangladesh, Sudan, Philippines and England.

Yoshisuke Kishida

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA

Vol. IV No.1 Spring, 1973

Changes in Cropping Patterns in APO Member Countries*

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I. Changes in Crop Varieties and Increase in Production

The food production in the later period of 1960's in this region has shown an appreciable increase. This increase was partly due to the introduction of new high-yielding crop varieties and was called "Green Revolution". Thus, the increase in food production was found mainly in the increase in yield rather than that in planted area of the crops.

This phenomenon has mainly been found in the food importing countries, such as Ceylon, India, Pakistan and the Philippines. During the period of 1967 to 1970, in India wheat production has increased by 21 per cent annually and in Pakistan, wheat and rice production has increased annually by 19 per cent and 3.3 per cent respectively.

According to the estimates made by the FAO,** increases in wheat and rice production in Far East region in 1968 are 43 and 6 per cent respectively compared with the production in the previous year, and in 1969, the same increases were 10 and 4 per cent respectively. In 1970, further increases in wheat and rice production were observed in this region, showing 8 and 6 per cent increases respectively compared with those in the previous year.

Though there has been somewhat slowing down trend of the increase, this remarkable increase in food production since 1967 has been brought by the dissemination of new high-yielding varieties of IRRI rice, CIMMYT wheat and other improved local varieties of these crops, improvement and expansion of irrigation facilities, the increase in the use of various agricultural requisites and progress in farming practices to meet the changes in crop varieties.

According to the survey made by the U. S. Department of Agriculture, the percentage of total wheat area planted to high-yielding varieties in 1969/70 was 45.6 per cent in Pakistan, 38.2 per cent in India, 19.3 per cent in Nepal and 7.4 per cent in Iran. The corresponding percentage for rice in the same year was 43.7 per cent in the Philippines, 11.5 per cent in Indonesia, 6.3 per cent in Pakistan and 8.0 per cent in the Republic of Vietnam. In Ceylon, the area under IRRI varieties of rice was only 3.9 per cent of the total area planted to rice in the same year, but if locally developed high-yielding varieties, such as H4, were included, the high-yielding varieties might represent more than 70 per cent of the total planted area of rice (See **Table 1**)

In Japan, the Republics of China and Korea, the yields of rice, wheat and other cereals are higher than in other Asian countries. In these countries, Japonica type rice varieties fertilizer response to which is higher than Indica type varieties and high-yielding rice varieties have been developed domestically or imported in earlier period. These were reasons for high yield of rice in these countries. Another reason for this was high pressure of labour to land or high density of population in these countries compared to other Asian countries. It will be found in the table attached to this text, showing agricultural population around two persons per hectare, though they are decreasing due to industrialisation in some of these countries (See **Table 2**). Similarly high pressure of labour to land was observed in Vietnam, Hong Kong, and Nepal, where yield per hectare of cereals was relatively higher. It was also found that the new high-yielding varieties have not been dissminated widely in the exporting countries with only exception of Nepal. Thailand is only introducing new high-yeilding varieties for experimental purposes, because the country is

Table 1. Total Planted Area and Area Under High-Yielding Varieties of Wheat and Rice in APO Member Countries in 1969/70

(Unit: 1,000 hectares)

	Total planted area	Area under HY varieties	%
Wheat *			
India[1]	16,000	6,111	38.2
Iran * *	4,700[2]	100[2]	2.1
Nepal[1]	388	75	19.3
Pakistan[1]	6,219	2,833	45.6
Rice *			
Ceylon[1]	671	26	3.9
India[1]	38,000	4,371	11.5
Indonesia[1]	7,972	749	9.4
Nepal[1]	1,174	50	4.2
Pakistan[1]	12,076	765	6.3
Philippines[1]	3,100	1,354	43.7
Rep. of Vietnam[1]	2,519	202	8.0

Source: 1) U.S. Department of Agriculture, "Imports and Plantings of high-yielding varieties of wheat and rice in the less developed nations", Washington, D.C., 1971, p. 101.

2) FAO, The State of Food and Agriculture", Rome, 1971, p. 101.

* All the countries except Iran, varieties included are (a) dwarf and semi-dwarf varieties developed at the International Wheat and Maize Improvement Centre (CIMMYT) in Mexico and the International Rice Research Institute (IRRI) in the Philippines, and (b) direct descendants of these varieties developed in national breeding programmes. The definition thus excludes a number of local improved varieties not derived from the CIMMYT and IRRI varieties.

* * Including Bostova No. 1 imported from U.S.S.R. and Mexican Inya 66 imported from Denmark etc. Expected to increase 350,000 hectars in 1971/72.

afraid of lowering in quality for export rice.

Facts indicated above will show that dissemination of the new high-yielding varieties has influenced the increase in food production. However, there are various problems to be overcome indisseminating new high-yielding varieties.

It is particularly observed in the dissemination of new high-yielding varieties of rice, showing lower percentage of area covered by new varieties than in the case of wheat with the exception of the Philippines. It is supposed that the dissemination of high-yielding varieties might be more difficult for rice than for wheat.

2. Increase in Production of Cereals and Importance of Diversification of Agriculture

As indicated in the foregoing sections, production of cereals has increased high during the period of these several years. This caused various problems concerning supply and demand of food grains in this region. The problems will be discussed in the following paragraphs.

At first, it is easily found from the statistics that food importing countries have decreased their import, while in turn, the exporting countries have decreased their export much during the same period. For instance, Ceylon decreased her import of rice from 976,000 metric tons (in terms of paddy) in 1964-66 average to 514,000 metric tons in 1968. India decreased her wheat import from 6,679,000 metric tons in 1964-66 average to 3,090,000 metric tons in 1968/69.

This means that the self-sufficiency of food (cereals) has been attained or greatly improved in these several years particularly in the food inporting countries. For instance, in Ceylon, the ratios of production to available supply of rice and all cereals were 46.5 per cent and 40.1 per cent respectively in 1964-66 average, while those in 1968 were 75.2 per cent and 58.1 per cent respectively. In India, in 1964-66 average the same ratios of wheat and all cereals were 61.1 per cent and 91.0 per cent respectively and those in 1968/69 were 86.4 per cent and 97.1 per cent respectively. In 1968/69 or 1969, Iran, India, Pakistan and the Philippines attained self-sufficiency of rice, though India is

Table 2. Some Indicators of Agricultural Input Materials

		Yield[1] mt/ha	Increase in yield[1] (Index)	Fertilizer[1] mt/ha	Agri. Chemical[2] kg/ha	Machinery[3] HP/ha	Labour[3] Pers./ha	Animal Head[3] /ha
		1967-68	Av. 1952-56 —1967-68					
Japan	I	5.14	146	371.3	11.60	2.664	2.16	0.30
Rep. of China	E	3.91	150	282.7	3.07	0.146	1.95	0.41
Rep. of Korea	I	2.84	124	210.5	2.17	0.003	1.96	0.30
Vietnam	I	2.05	159	43.6	0.02	0.023	2.10	0.61
Hong Kong	I	2.00	71	—	—	—	—	—
Nepal	E	1.87	104	0.6	0.02	0.004	2.49	1.20
Ceylon	I	2.05	143	43.1	1.42	0.110	1.20	0.37
Thailand	E	1.73	128	7.5	0.53	0.054	1.10	0.46
Indonesia	I	1.63	108	7.4	0.01	—	—	—
Pakistan	I	1.31	120	10.2	0.07	0.013	1.09	0.72
Philippines	I	1.09	110	16.4	0.27	0.023	0.71	0.26
India	I	1.00	123	11.0	0.27	0.008	0.90	0.51
Iran	I	1.00	97	5.7	0.15	0.154	0.37	0.12
Average		1.29	121	22.9	0.53	0.087	0.99	0.50

I: Importing countries of food grains

E: Exporting countries of food grains

Source of data: 1) Symposium on Fertilizer Economy, APO, 1971

2) Symposium on Agricultural Chemicals, APO, 1971

3) Expert Meeting on Agricultural Mechanization, 1968.

yet importing to accumulate buffer stock.

On the other hand, in rice-exporting countries, the export of rice decreased much these several years. For instance, Thailand decreased her export from 2,757,000 metric tons (in terms of paddy) in 1964-66, to 1,050,000 metric tons in 1969, while the production increased from 11,645,000 metric tons to 13,400,000 metric tons during the same period. In the Republic of China, the export of rice decreased from 272,000 metric tons (in terms of paddy) in 1964-66 average to only 44,000 metric tons in 1969, while the production increased from 3,045,-000 metric tons to 3,211,000 metric tons during the same period.

Table 3. The Ratio of Production to Total Available Supply

	1960–62	1964–66	Nearest year of 1969
Ceylon			
Rice	57.4%	46.5%	75.2%
Wheat	0.0	0.0	0.0
All Cereals	52.2	40.1	58.1
Rep. of China			
Rice	105.6	109.1	106.3
Wheat	12.6	7.1	1.7
All Cereals	93.2	96.6	79.3
Hong Kong			
Rice	—	3.1	3.4
Wheat	—	0.0	0.0
All Cereals	—	2.3	2.6
India			
Rice	98.2	98.0	100.1
Wheat	76.7	61.1	86.4
All Cereals	95.2	91.0	97.1
Indonesia			
Rice	—	94.9	94.5
Wheat	—	0.0	0.0
All Cereals	—	95.3	94.2
Iran			
Rice	99.2	97.5	100.0
Wheat	85.8	93.5	83.3
All Cereals	90.1	95.3	88.2
Japan			
Rice	101.5	97.1	104.0
Wheat	39.8	25.2	9.1
All Cereals	79.9	66.1	57.3
Rep. of Korea			
Rice	—	107.7%	83.3%
Wheat	—	38.5	17.6
All Cereals	—	96.6	65.4
Nepal			
Rice	—	118.5	104.2
Wheat	—	95.4	100.9
All Cereals	—	112.7	103.7
Pakistan			
Rice	99.1%	99.5%	101.6%
Wheat	77.5	75.6	87.4
All Cereals	94.2	94.8	97.9
Philippines			
Rice	97.6	89.3	100.0
Wheat	0.0	0.0	0.0
All Cereals	91.8	84.8	89.0
Thailand			
Rice	—	132.2	107.2
Wheat	—	0.0	0.0
All Cereals	—	142.8	113.4
Rep. of Vietnam			
Rice	—	90.8	89.2
Wheat	—	0.0	0.0
All Cereals	—	88.4	84.0

Source: Annex Table I, II & III.

Japan is a special case. Her import of rice in 1964-66 average was 966,000 metric tons (in terms of paddy), while in 1970, she exported more than 1,000,000 metric tons of rice (in terms of paddy), and her stock of rice nonetheless increased 365,000 metric tons. Her average level of production in terms of brown rice (dehusked rice) is around 14,000,000 metric tons, while her average level of consumption is around 12,000,000 metric tons due to a decrease in per capita consumption and low rate of annual population growth (between 0.9 to 1.0%). Thus, accumulated government stocks of rice at the beginning of the 1969 rice year reached as high as 7,026,000 metric tons.

However, her import of maize and sorghum increased tremendously from 5,260,000 metric tons in 1964-66 average to 8,825,000 metric tons in 1970. In the case of maize and sorghum, there is only a negligible amount of domestic production, which has tended to decrease. In the case of wheat, too, the production tended to decrease from 1,185,000 metric tons in 1964-66 average to only 474,000 metric tons in 1970, while the import increased from 3,702,000 metric tons to 4,621,000 metric tons during the same period.

Consequently, the self-sufficiency ratio of rice increased from 97.1 per cent in 1964-66 average to 104.0 per cent in 1970, while that of wheat decreased from 25.2 per cent to only 9.1 per cent during the same period. For all cereals including maize and sorghum the raito also decreased from 79.9 per cent in 1960-62 to 66.1 per cent in 1964-66 average, and a further decrease to 57.3 per cent was observed in 1970.

This is a typical example of

the relationship between change in food habits and food production pattern.The demand for rice showed a negative response to an increase in per capita income in Japan, while the high-income elasticity of demand for animal foods was observed under the condition of high-income level and extremely high rate of economic growth. These caused a decrease in consumption for rice and an increase in consumption of animal products, particularly the decrease in rice consumption accelerated by the low population growth rate. The rapid increase in demand for animal products caused a high increase in import demand for maize and sorghum, namely feed grains, since there is only a small amount of domestic production. In Japan, the Government is now taking a policy for cutting acreage of paddy field which has been rather successfully done in these few years. However, prices of vegetables, fruits and animal products have gone up rapidly in these several years, reflecting strong demand for them.

Even in the low income countries, the demand for some kinds of crop showed negative effect associated with the increase in income. Such crops as coarse grains and starchy roots were the examples. Pulses showed low income elasticity in these countries. For such crops as rice and wheat, on the other hand, the elasticities of demand were higher than for foods indicated above and in some countries, the demand for fruits and vegetables or fats were also becoming "necessary" foods. In high-income countries like Japan, the demand for animal products was increasing. There is no country which has negative economic growth rate, and per capita income is ever growing.

This will cause the change food habits more in the future, even though there have been traditional food habits in these countries. This requires change in cropping pattern of the food production to meet the changes in food habits. Even changes in habits in other countries become impetus of the exports of food or feed crops in the exporting countries. A rapid increase in maize production in Thailand has been stimulated by the rapid increase in import demand for maize as feed grains in Japan.

In this connection, it should be noticed that even though the elasticities of demand for coarse grains and starchy roots are becoming low or even showing negative coefficients as foods, if demand for animal food become high, the demand for these crops as feeds would become very high. Actually, the demand for coarse grains and oil-cakes is extermely high in the developed countries including Japan. This requires more production of feed crops. The same thing will also happen domestically in the future in the developing countries.

3. Changes in Cropping Pattern

(1) Trend in Changes in Cropping Pattern

Broadly, it can be said that there are two types of cropping patterns among many of the APO member countries: One is more concentrated on commercial crops and the other depends more upon food crops. Countries belonging to the first category are Indonesia, the Philippines and Ceylon who export such commercial crops as rubber, sugar, coconut, tea and hard fiber. Pakistan and India also have quite a large planted area of jute and tea. On the other hand, Thailand and the Republic of China are representative rice exporting countries among the member countries. The Republics of Korea and Vietnam had been rice exporting countries in the past, and the area under rice at present is still high.

Such a condition had been called "mono-culture" ecomomy, or since commercial crops were grown in the plantations in concessional terms by the metropol countries, it had also been called dual economy. Though such condition has largely been changed after World War II, the agricultural production patterns are still rather rigid or not widely diversified yet. However, almost all the member countries, which had imported food, have been concentrating their efforts to attain self-sufficiency of food during the period of these ten years.

Quite recently, there has been a big change in the condition of food production in this region as mentioned earlier. It is the increase in food grain production mainly in the food importing countries in this region. Such a change called for another change in production, because the increased production of cereals has been made under the condition of changing food consumption pattern in many of the member countries. It can also be said that there emerged a possibility to diversify the cropping pattern in these countries, because the land required to produce the same amount of food grains has become smaller than before, as a result of increased yield per hectare. The needs for diversification of agriculture in relation to the changes in demand. In short, the food production, particularly, the cereal production, as well as agriculture production should be diversified to meet the change in their demand, otherwise it would cause a surplus of food supply from the national as well as international points of view.

However, the production pattern of food as well as agriculture is still cereal oriented, and the rate of increase in food production is the highest among agricultural production as shown in the **Table 4** & **Table 5**. For instance, in Ceylon cereals, mainly rice increased by 145 per cent during the period of 1952-56

Table 4. Percentage Distribution of Crops

	Rice	Wheat	Other cereals	Total cereals	Meat	Fruit	Veg.	Other Crops	Total	(1965) Percentage of agri. population	(ha) Average size of holding
Ceylon	20	—	—	20	3	6	4	67	100	54	1.59
Rep. of China	26	—	1	27	32	9	5	27	100	47	1.11
Hong Kong	—	—	—	—	—	—	—	—	—	6	—
India	26	9	10	45	3	4	5	43	100	70	2.62
Indonesia	36	—	7	43	12	4	3	48	100	66	1.06
Iran	6	30	4	40	12	3	5	40	100	54	8.29
Japan	26	2	2	30	13	8	11	38	100	24	0.90
Rep. of Korea	33	4	17	54	11	2	8	25	100	54	—
Nepal	44	6	17	67	7	1	2	23	100	92	1.22
Pakistan	27	10	2	39	6	4	1	50	100	74	2.37
Philippines	26	—	9	35	19	7	3	36	100	59	3.66
Thailand	52	—	6	58	10	5	3	24	100	78	3.64
Vietnam	62	—	—	62	19	5	1	13	100	85	1.57
Far East Ave.	31	5	7	43	8	5	5	39	100	48	6.17

Source: FAO Index Number of Gross Agricultural Production by Commodity Group, Monthly Bulletin of Agricultural Economics & Statistics, May 1971.

average to 1970. In India, Iran, Indonesia and the Philippines, all cereal production increased by 66, 48, 74 and 98 per cent respectively during the same period. As mentioned earlier, Pakistan and India have increased wheat production the most.

However, the Republic of China, Japan and the Republic of Korea have taken another direction. In these countries, the increase in meat or fruit production has been the highest among agricultural production during the same period. High increase in coarse grain production in the Republic of China is supposed to show the increased demand for feed grains. Extremely high rate of increase in coarse grains in Thailand has reflected increased export demand for feed grains resulting mainly from increased import demand of Japan, as stated before.

This shows that the change in cropping pattern has already been started in some extent.

Let us see the present situation of cropping pattern in the member countries. From **Table 6** showing the percentage distribution of planted area by crop by country, it is found that the countries like Thailand, the Republic of Korea and Pakistan have more area under food crops such as cereals, starchy roots and pulses. Particularly, Thaliand and the Republic of Korea have high percentage of rice, and rice, wheat and barley altogether occupying more than 70 per cent of the total planted area.

Though the table does not indicate the percentage in detail, India and Pakistan have quite a large area of tea and jute (the latter figure might be included in others), so that the percentage of food crops is smaller than in the former two countries.

The countries such as Ceylon, Indonesia, and the Philippines show smaller percentage of planted area devoted to such food crops as mentioned earlier, particularly so in the case of Ceylon. In turn, these countries have larger area of commercial crops such as coconut, sugar cane, tea, rubber, etc.

The Republic of China and Japan show lower percentages of planted area under cereals, though both had shown quite large percentage of the planted area in the past. Diversification of agriculture has taken place according to the change in demand for food, though they have yet various problems in this regard. Thailand also has made progress in diversification of agriculture, which will be discussed in detail later.

The situations mentioned above relate mainly to conditions of the

Table 5. Agricultural Production Index by Crop (1970) (1952−56=100)

	Total agri.	Cereals	Grains	Coarse Grains	Meat	Fruit	Veg.
Ceylon	154	245	123	123	104	162	143
Rep. of China	189	152	172	407	223	569	237
Hong Kong	—	—	—	—	—	—	—
India	148	166	178	138	118	142	134
Indonesia	133	148	125	125	148	136	132
Iran	169	174	164	118	156	93	144
Japan	185	99	31	30	463	364	214
Rep. of Korea	217	180	199	201	332	380	239
Nepal	108	109	130	118	116	198	198
Pakistan	165	182	209	120	156	232	143
Philippines	174	198	295	295	150	240	167
Singapore	—	—	—	—	—	—	—
Thailand	220	209	2,545	2,545	150	325	155
Vietnam	186	218	106	106	179	153	202

Source: The same with the previous table.

Table 6. Percentage Distribution of Planted Area in APO Member Countries

	Ceylon[2] 1966	Rep. of China[1] 1970	India[1] 1966/67	Indonesia[2] 1967	Japan[3] 1970	Rep.of Korea[1] 1970	Pakistan[1] 1970	Philippines[1] 1970	Thailand[1] 1960
Cereals	33.7	49.0	59.8	57.3	54.6	71.1	68.8	61.9	73.1
Rice	31.5	47.0	22.4	42.4	46.3	32.7	38.1	34.8	70.2
Wheat	—	0.1	8.3	—	3.6	) 32.7	22.8	—	—
Barley	—	0.0	1.8	—	3.6		0.7	—	—
Maize	0.7	1.4	3.3	14.9)	1.1)	5.7)	7.2	27.1	2.9
Other coarse grains	1.6	0.5	24.0	—				—	—
Starchy roots	4.2	15.6	—	10.5	4.4	5.6	0.4	2.9	0.9
Pulses	—	9.2	13.7	5.7	5.3	10.8	5.4	0.9	2.2
Vegetables	—	8.2	) 2.1	—	10.8	5.4	0.8	0.7	1.1
Fruits	—	7.3		—	6.6	1.4	1.1	4.5	11.4
Sugar cane	0.5	5.6	1.5	0.8	—	—	2.7	4.1	1.6
Tobacco	0.4	—	—	1.3	—	1.1	—	—	—
Cocoa	—	—	—	—	—	—	—	0.1	—
Coffee	—	0.0	0.1	—	—	—	—	0.6	—
Tea	14.7	2.1	0.2	0.7	0.8	—	0.2	—	—
Oil palm	—	—	—	—	—	—	—	—	—
Coconut	26.9	—	0.6	11.1	—	—	—	21.1	1.6
Rubber	13.9	—	—	10.8	—	—	—	—	—
Mulberry	—	—	—	—	2.6	2.6	—	—	—
Other crops	5.7	3.3	22.0	1.8	14.9	2.0	20.6	3.3	8.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source of data: 1) Answer to the Questionnaire of APO
2) Economic Survey of Asia and the Fareast, U. N., 1969
3) Pocketbook of Agriculture, Forestry and Fisheries Statistics (in Japanese), 1972.

region at present. Let us see the changes in cropping pattern by country during the period from 1940 or 1950 to 1970 (Refer to **Table 7** (a)—(i)).

In India, the planted area of cereals increased from around 81,000,000 hectares to 93,600,000 hectares or by 16 per cent during the period of 1950/51 to 1966/67, and in Pakistan, the corresponding area also increased around 21 per cent during the period of 1950 to 1970. In the Philippines, the planted area of cereals was around 3,000,000 hectares in 1940 which increased to 5,152,000 hecatares in 1960 and a futher increase was observed in 1970 to 5,533,000 hectares.

In the Republic of China, the increase in planted area of cereals had been very high during the period of 1940 to 1951. It increased from around 652,000 to 806,000 hectares or around 24 per cent during the period. However, during the period of 1951 to 1960 it increased by only 1 per cent, and during the period of 1960 to 1970, it decreased by 0.6 per cent. Among the planted area of cereals, that of rice increased by around 21 per cent during the period of 1940 to 1951, but since then become almost stagnant. Only the planted area of maize increased very high during the latter period. This increase in the planted area was supposed to reflect an increase in demand for feeds in the domestic market due mainly to the increased demand for animal foods, and the stagnation of rice area reflected a decrease in export demand and lowered increase rate of demand for rice in domestic market.

In Thailand, on the other hand, the planted area of both rice and maize has continuously increased high during the period of 1950 to 1970. The planted area of rice increased by 33 per cent, and that of maize in 1970 was as high as 19 times the area in 1950. The increase in rice planted area was due partly to the larger foreign market and partly to the high increase rate of population, than in the case of the Republic of China. The increase in planted area of maize was due mainly to the increased external demand.

However, it should be noticed that in the case of cereals, the increase rate of production is becoming higher than that of area indicated above, so that even from the decreased land area of cereals the production would be increased.

As indicated in the foregoing sections, Japan is an exceptional case. During the period of 1950 to 1960, the planted area of rice was still growing, but particularly during the period from 1965 to 1970, it tended to decrease. Though the percentage of total planted area devoted to rice was still the highest, the actual area under rice decreased by around 10 per cent during the latter period. High rate of increase during the former period and high percentage of area under this crop even in the latter period were due mainly to high rice prices set under the Government price policy. The price was as high as around US$385 per metric ton in terms of brown rice in 1970. However, the support price remained unchanged for some years, and the Government started the policy for cutting the acreage of planting rice. This caused a decrease in the planted area in this country.

With the exception of Japan, both cultivated land area and planted area of all crops are still increasing. However, the expansion of cultivated land area was rather limited and the increase in total planted area was also not so large relative to the cultivated area, with the exceptions of the Republics of China and Korea. Thus there has been some change in cropping pattern of already cultivated land, since in food deficit countries the area under

Table 7. Planted Area by Crop and Percentage Distribution of the Area

(a) Republic of China (Unit: 1,000 hectares)

	Planted area				Percentage distribution			
	1940	1950	1960	1970	1940	1950	1960	1970
Cereals	651.9	805.7	815.0	810.3	55.6	54.3	51.1	49.0
Rice	638.6	770.3	766.4	776.1	54.4	51.9	48.1	47.0
Wheat	5.6	18.3	25.2	2.0	0.5	1.2	1.6	0.1
Barley	1.0	2.5	0.4	0.5	0.1	0.2	0.0	0.0
Maize	1.9	5.0	13.9	22.6	0.2	0.3	0.9	1.4
Sorghum	3.2	2.7	3.2	4.0	0.3	0.2	0.2	0.2
Millet	1.5	6.9	5.9	5.0	0.1	0.5	0.4	0.3
Starchy roots	142.2	246.9	353.0	258.7	12.1	16.7	15.9	15.6
White potato	0.3	0.3	0.7	2.4	0.0	0.0	0.0	0.1
Sweet potato	132.5	233.1	235.4	228.7	11.3	15.7	14.8	13.8
Cassava	7.6	9.8	13.0	24.7	0.6	0.7	0.8	1.5
Taro	1.9	3.8	3.9	2.8	0.2	0.3	0.3	0.2
Other tuber crops	—	—	—	—	—			
Pulses	46.0	120.5	189.3	151.4	3.9	8.1	11.9	9.2
Vegetables	38.3	70.2	87.0	136.3	3.3	4.7	5.5	8.2
Fruits	40.2	31.4	37.8	119.9	3.4	2.1	2.3	7.3
Sugar cane	169.0	121.9	95.5	87.5	14.4	8.2	6.0	5.3
Tree crops	46.3	42.0	48.6	34.5	3.9	2.9	3.0	2.1
Coffee	0.6	—	0.1	0.1	0.0	—	0.0	0.0
Tea	45.6	42.0	48.4	34.4	3.9	2.9	3.0	2.1
Others	40.1	44.9	68.5	54.6	3.4	3.0	4.3	3.3
Total Planted area	1,174.0	1,483.5	1,594.7	1,653.2	100.0	100.0	100.0	100.0
Total arable land area	861.0	874.0	869.0	905.0				
Intensity	136.5	169.7	183.6	182.6				

Source of data: Answer to the Questionnaire of APO.

(b) Hong Kong (Unit: 1,000 hectares)

	1950	1960	1970
Rice	9,035	7,478	4,568
Vegetables	—	1,793	3,784
Fruits	—	587	641
Total	—	9,858	8,993

cereals expanded. In these countries, the expansion of area under rice and wheat was large.

On the other hand, in India and Pakistan, the planted area of pulses has decreased these several years. The planted area of some of the coarse grains has also tended to decrease in these countries. The planted area of sugar cane has also tended to decrease in some countries (the Republic of China and Thailand), but in some other countries (India, Pakistan and the Philippines), it is still growing. As mentioned earlier, the demand for sugar in this region is expanding particularly in the developing countries. However, the planted area would not be decided only by the domestic market, the decrease also reflected the condition in the international market. This was, however, quite different from country to country. For instance, the increase in planted area of sugar cane in the Philippines reflected not only the increased demand in the domestic market, but also the favourable sugar export agreement with the U. S. A.

In almost all the countries in the region, the expansion of planted area of fruits and vegetables has been remarkable in these several years. In some countries, the planted area of commercial crops, particularly that of coconut and oil palm, has been expanded. However, the planted area of tea has decreased or become stagnant in almost all the countries where it is grown, reflecting the unfavourable demand conditions in the international market.

From the facts mentioned above, changes in the planted area were mainly found in respect of commercial crops, with the exception of cereals. It reflected that, the demand for foods other than cereals, and

Table 7. (c) India (Unit: 1,000 hectares)

	Planted area			Percentage distribution		
	1950/51	1960/61	1966/67	1950/51	1960/61	1966/67
Cereals	80,641	91,899	93,582	61.1	60.2	59.8
Rice	31,056	34,056	35,054	23.5	22.3	22.4
Wheat	10,010	12,931	12,878	7.6	8.5	8.3
Barley	3,198	3,140	2,835	2.4	2.1	1.8
Maize	3,250	4,401	5,118	2.5	2.9	3.3
Sorghum (jawar)	15,554	18,426	18,072	11.8	12.1	11.6
Bajra	11,998	13,949	14,493	9.1	9.1	9.3
Other coarse grains	5,576	4,997	4,841	4.2	3.3	3.1
Starchy roots	—	—	—			
Pulses	20,554	23,665	21,561	15.6	15.4	13.7
Vegetables & Fruits	2,249	2,649	3,287	1.7	1.7	2.1
Sugar cane	1,757	2,417	2,374	1.3	1.6	1.5
Tree crops	1,028	1,164	1,343	0.8	0.8	0.9
Cocao	—	—				
Coffee	90	120	146	0.1	0.1	0.1
Tea	323	328	346	0.2	0.2	0.2
Oil palm	—	—				
Coconut	615	716	851	0.5	0.5	0.6
Other crops	25,663	30,978	34,420	19.5	21.3	22.0
Total planted area	131,893	152,772	156,567	100.0	100.0	100.0
		(1959/60) 149,260	(1967) 163,700			

Table 7. (d) Iran (Unit: 1,000 hectares)

	Planted area			
	1940	1950	1960	1970
Cereals	5,105	5,344	5,806	5,996
Rice	205	240	300	360
Wheat	4,200	4,500	4,700	4,800
Barley	700	600	800	800
Maize	—	—	—	25
Sorghum	2	4	6	11
Millet	—	—	—	—
Starchy roots	—	—	—	—
White potato	59	67	70	75
Pulses	—	—	—	200
Sugar	110	100	120	155
Tea	35	35	30	25
Tobacco	20	21	20	22
Other crops	31	30	27	27

other agricultural products in domestic market has been rather small in the countries of this region.

However, it should be noticed that the expansion of the planted area of cereals has become or is becoming smaller than that of production and the demand for some kind of coarse grains has tended to decrease, though the increase in production was rather high.

The same thing was also observed in the case of starchy roots and pulses, though the increase in yield has been much smaller than that of cereals.

The change in cropping pattern may have to do with the demand not only in the domestic market but also in the export market. In this connection, the increase in domestic or foreign demand for animal products should not be lost sight of. Indeed, the demand for feeds like both cereals and oil cakes (or oil seeds as their raw materials) is quite high in the developed countries, reflecting the strong demand for animal products.

Another consideration which should be made is the intensification of land utilisation, which is another strategy to increase agricultural productivity. This problem should be observed from the viewpoint of individual farmers rather than from the national viewpoint

Table 8 shows the ratio of total planted area against total cultivated land area (arable land area) or the intensity rate of land utilisation in the selected APO member countries. According to the table, the intensity of land utilisation in the highest in the Republic of China where the pressure of labor to land is most serious, farmers in this country utilise land 1.8 times a year on the average by cultivating the arable land of only 0.14 hectare per person engaged in agriculture and using fertilizer amounting to as high as 317 kgs (In terms of plant nutrients) per hectare.

In this country the land is intensively cultivated and the farmers use more labor per hectare, applying much fertilizer as indicated above. Many of the farmers in this country grow rice twice a year and plant vegetable seedlings between the row of rice plants still standing on the field, and the vegetables are grown between the period of the first crop of rice and the second crop

Table 7. (e) Japan (Unit: 1,000 hectares)

	Planted Area					Percentage distribution of planted area				
	1941	1950	1960	1965	1970	1941	1950	1960	1965	1970
Cereals	5,233	5,197	4,972	4,300	3,443	63.4	67.3	61.2	57.8	54.6
Rice	3,182	3,036	3,308	3,255	2,923	38.6	39.3	40.7	43.8	46.3
Wheat	) 1,793	) 1,893	602	476	229	) 21.7	) 24.5	7.4	6.4	3.6
Barley			838	422	225			10.3	5.7	3.6
Oat and rye	—	—	80	63	29	—	—	1.0	0.8	0.5
Other food grains	258	268	144	84	37	3.1	3.5	1.8	1.1	0.6
Starchy roots	492	595	527	459	280	6.0	7.7	6.5	6.2	4.4
Sweet potatoes	311	401	330	257	129	3.8	5.2	4.1	3.5	2.0
White potatoes	181	194	197	202	151	2.2	2.5	2.4	2.7	2.4
Pulses	518	635	642	485	337	6.3	8.2	7.9	6.6	5.3
Vegetables	444	407	615	692	683	5.4	5.3	7.6	9.3	10.8
Fruits	137	101	254	356	416	1.7	1.3	3.1	4.8	6.6
Industrial crops	307	253	398	316	205	3.7	3.3	4.9	4.2	3.3
Tea	39	28	49	49	52	0.5	0.4	0.6	0.7	0.8
Mulberry	494	176	166	164	163	6.0	2.3	2.0	2.2	2.6
Forage and Manure	590	304	506	611	733	7.0	3.9	6.2	8.2	11.6
Others	—	22	—	—	—	—	0.3	—	—	—
Total planted area	8,254	7,719	8,129	7,430	6,312	100.0	100.0	100.0	100.0	100.0
Arable land area	5,867	5,090	6,071	6,004	5,796					
Intensity of land	141	152	134	124	109					

Table 7. (f) Republic of Korea (Unit: 1,000 hectares)

	Planted area			Percentage distribution		
	1961	1965	1969	1961	1965	1969
Cereals	2,312	2,665	2,521	75.0	74.3	71.1
Rice	1,137	1,238	1,160	36.9	34.5	32.7
Wheat and barley	970	1,211	1,161	31.5	33.8	32.7
Coarse grains	205	216	200	6.6	6.0	5.7
Starchy roots	110	214	198	3.6	6.0	5.6
Pulses	341	368	384	11.1	10.3	10.8
Vegetables	170	151	193	5.6	4.2	5.4
Fruits	23	43	51	0.7	1.2	1.4
Industrial crops	82	61	72	2.7	1.7	2.0
Tobacco	20	34	39	0.6	0.9	1.1
Mulberry	23	51	94	0.7	1.4	2.6
Total planted area	3,083	3,587	3,552	100.0	100.0	100.0
Total arable land area	2,049	2,275	2,338			
Intensity	150	158	152			

of rice and also between the period of the second crop of rice and the first crop of rice. They call it relay farming. Such farming has been benefited from the favourable national conditions in this country where various crops can be grown at any time of the year.

Table 7. (g) Pakistan (Unit: 1,000 acres)

	Planted area			Percentage distribution		
	1950	1960	1970	1950	1960	1970
Cereals	38,410	41,171	46,364	64.4	65.7	68.8
Rice	22,399	24,804	25,720	37.6	39.6	38.1
Wheat	10,893	11,603	15,334[1]	18.3	18.5	22.8
Barley	511	536	460[1]	0.8	0.9	0.7
Maize	947	1,207	1,589	1.6	1.9	2.4
Sorghum	1,256	1,177	1,380	2.1	1.9	2.0
Millet	2,404	1,844	1,881	4.0	2.9	2.8
Starchy root	—	—	—			
Potatoes	—	186	253[2]	—	0.3	0.4
Others	—	—	—			
Pulses	4,565	4,606	3,666[2]	7.7	7.4	5.4
Vegetables	697	575	573[3]	1.2	0.9	0.8
Fruits	—	—	757[3]	—	—	1.1
Sugar cane	693	1,238	1,824	1.2	2.0	2.7
Tree crops	—	—	—	—	—	—
Tea	75	79	110	0.1	0.1	0.2
Coconut	—	—	64[2]	—	—	0.2
Others	15,170	14,765	13,709	25.4	25.4	20.4
Total	59,610	62,620	67,420[3]	100.0	100.0	100.0

(1) The first estimate (2) 1969/70 (3) 1968/69

In the Republic of Korea, the land is also intensively utilised (1.5 times a year on the average), where the pressure of labour to land is as heavy as in the Republic of China, and also fertilizer use per hectare is as high as 207 kgs in terms of plant nutrients. In this country, the climatic condition is more severe, particularly in winter, compared with that in the Republic of China, In spite of this, the intensity of land utilisation is high. However, the land utilisation in this country is highly concentrated upon the cereals, among which the planted area of rice, wheat and barley is quite high. The percentage of the planted area under cereals is the highest among the member countries as indicated before. It is also found that the planted area of rice which had been a little higher than that of wheat and barley in the past became almost the same as the latter area in 1969. In this country, after the rice harvested in October or November, wheat and barley seeds are sown, so that the paddy field is used all over a year in the area where climatic conditions allow it and irrigation and drainage facilities exist. Sometimes in some area, potatoes or vegetables are also grown in the paddy fields. However, the intensity rate of land utilization is becoming less, showing 158 in 1965 and

Table 7. (h) Philippines (Unit: 1,000 hectares)

	Planted area				Percentage distribution			
	1940	1950	1960	1970	1940	1950	1960	1970
Cereals	2,993.3	3,123.0	5,152.0	5,533.0	58.8	61.5	67.8	61.9
Rice	2,080.4	2,214.0	3,306.5	3,113.4	40.8	43.6	43.5	34.8
Wheat	—	—	—	—	—	—	—	—
Barley	—	—	—	—	—	—	—	—
Maize	912.9	909.0	1,845.5	2,419.6	17.9	17.9	24.3	27.1
Sorghum	—	—	—	—	—	—	—	—
Millet	—	—	—	—	—	—	—	—
Starchy roots	179.4	185.5	291.2	255.9	3.5	3.7	3.8	2.9
White potato	0.1	—	2.1	3.0	0.0	—	0.0	0.0
Sweet potato	120.1	120.3	172.2	134.6	2.4	2.4	2.3	1.5
Cassava	39.8	39.1	79.5	82.6	0.8	0.8	1.0	0.9
Taro	11.8	16.2	22.2	24.1	0.2	0.3	0.3	0.3
Other tuber crops	7.6	10.0	15.2	11.6	0.1	0.2	0.2	0.1
Pulses	47.1	55.0	102.5	81.0	0.9	1.1	1.3	0.9
Vegetables	14.5	20.6	82.6	65.5	0.3	0.4	1.1	0.7
Fruits	201.4	211.2	342.5	399.6	4.0	4.2	4.5	4.5
Sugar cane	229.7	129.5	242.2	366.1	4.5	2.5	3.2	4.1
Tree crops	1,062.9	998.9	1,096.5	1,945.3	20.9	19.7	14.4	21.7
Cocoa	4.6	4.0	6.6	8.3	0.1	0.1	0.1	0.1
Coffee	7.1	9.8	30.5	54.0	0.2	0.2	0.4	0.6
Coconut	1,051.2	985.0	1,059.5	1,883.0	20.6	19.4	13.9	21.1
Other crops	366.3	352.5	286.4	295.0	7.1	6.9	3.9	3.3
Total planted area	5,094.6	5,076.3	7,595.9	8,941.3	100.0	100.0	100.0	100.0
Arable land area	—	—	6,696.2	8,546.0				
Intensity of land	—	—	113	105				

Table 7. (i) Thailand (Unit: 1,000 hectares)

	Planted area				Percentage distribution
	1940	1950	1960	1970	1970
Cereals	—	5,576	7,203	8,111	73.1
Rice	3,937	5,540	6,917	7,376	70.2
Wheat	—	—	—	—	—
Barley	—	—	—	—	—
Maize	—	36	286	700	2.9
Sorghum	—	—	—	35	—
Millet	—	—	—	—	—
Starchy roots	—	—	92	—	0.9
White potato	—	—	0	1	0.0
sweet potato	—	—	12	40	0.1
Cassava	—	—	72	130	0.7
Taro	—	—	4	—	) 0.1
Other tuber crops	—	—	4	—	
Pulses	—	150	214	190	2.2
Vegetables	—	—	111	—	1.1
Fruits	—	—	1,127	—	11.4
Sugar	—	47	158	134	1.6
Tree crops					
Coconut	52	80	155	—	1.6
Other crops	—	393	795	—	8.1
Total planted area		—	9,855	—	100.0
Arable land area			9,746	—	
Intensity			101.4		

152 in 1969. This was partly due to the unfavourable climatic condition, particularly for rice, and partly due to the shortage of labour.

In Japan, the intensity rate of land utilisation was 152*** in 1950, but since then it has tended to decline. It became 134 in 1960 and decreased to 134 in 1965 and at last to only 109 in 1970. In this country, the pressure of labour to land had been very serious in the past. Even in 1950, the arable land area per person engaged in agriculture was only 0.13 hectare which was smaller than that in the Republics of China and Korea at present. However, this area per person increased to 0.25 hectare in 1968. However, 0.25 hectare per person is still smaller than in other member countries, except the Republics of China and Korea. On the other hand, fertlizer application per hectare is the highest among member countries.

The reason for the decline in the intensity of cultivated land utilisation was that the labour has become short during the period of these two decades, because of a rapid industrialisation of the country and the growing of ordinary crops particularly winter crops, mainly wheat and barley, became less profitable to farmers than before. Many of them preferred to go out to the cities to get better jobs rather than to cultivate the land particularly in winter. This resulted in a sharp decline in the planted area and production of wheat and barley in recent years as indicated in the previous section. Many farmers in suburban areas and now in other areas, too, use vinyl or green houses growing high-quality vegetables or flowers which sell at high prices. In this case, the profits earned from them were much higher than those earned from other crops or sometimes even higher than from working in other jobs, but the land value became extremely high in suburban areas, in particular, the high profit could not cover the rent even in growing such crops. The problem concerned with relatively less decrease in planted area of rice has already been indicated in the previous section.

In other countries, the arable land area per person in agriculture is more than twice as large as in the two Republics mentioned above. Compared with that in the countries of the other regions particularly American Continent and Oceania, however, the land area per person is very small. Fertilizer application per hectare in those countries is also extremely small.

In India and Pakistan, the planted area is smaller than the arable land area, although accurate data both on arable land and planted area are lacking. However, these two countries have so-called "Monsoon" climate which distinctly divides a year into dry and wet seasons; one half of a year has little rain and

Table 8. Some Indicators for Intensification of Agriculture in Selected APO Member Countries

	Year	Arable land area (1,000ha) (1)	Planted area (1)	Intensity rate of land utilization (1)	Arable land area per pers. in agri. (1968) (2)	Fertilizer consumption per hectare (1968) (2)
Rep. of China	1970	905	1,653	183	0.14ha.	317kg.
India	1966/67	159,690	156,567	98	0.46	11*
Japan	1970	6,071	8,129	134	0.25	405
Rep. of Korea	1969	2,338	3,552	152	0.14	207
Pakistan	1970	28,358	27,284	96	0.32	12
Philippines	1970	8,546	8,941	105	0.43	17
Vietnam	1970	9,746	9,855	101	0.45	9

Source: (1) From Table 7.
(2) "State of Food and Agriculture, 1971", FAO, Rome, 1971.

A well laid out rice field with an efficient water control system.

the other half much rain. This influences the cropping pattern of the countries, and makes the double cropping more difficult than in other countries.

In these two countries, the crops are still concentrated largely on cereals, and some commercial crops such as sugar cane, cotton, jute and tea are also grown by plantations or individual farmers.

The Philippines and Thailand have similar conditions as far as the land area per person in agriculture is concerned (0.43 and 0.45 hectare per person respectively, or about three times as big as in the Republics of China and Korea). Like India and Pakistan, these countries are also under the influence of Monsoon climate. However, the Philippines has more commercial crops such as coconuts, tabacco, abaca, sugar cane, etc. On the other hand, the Thailand mainly grew and exported rice. Even at present around 70 per cent of the land is used for rice cultivation, though agriculture is being diversified with expanded area under other crops. Expanded area planted to maize has already been explained earlier. In the Philippines, the intensity rate of land utilisation was around 113 in 1960 and around 105 in 1970, but the total planted area expanded to around 7,600,000 hectares in 1960 and to 8,941,000 hectares in 1970, as against only around 5,000,000 hectares before 1950. In this country, fertilizer application was 17 kgs per hectare which was higher than in India, Pakistan and Thailand.

Thailand is famous for the progress in her diversification of agriculture, as mentioned earlier. It was noticeable in respect of maize, sorghum, kenaf and cassava, but the most successful result was found in maize by expanding foreign market.

From the viewpoint of individual farmers, the problem of diversification of agriculture is a little different from that on a national basis. Generally speaking, the labour in this region is abundant and the pressure of labour to land is more serious, though it differs from country to country. Without fuller utilisation of labour, therefore, income of farmers would not be increased, though the marginal productivity of labour might fall because the land is a limiting factor. Labour intensive cultivation which one would see in Taiwan, Province of the Republic of China is a good example for this.

According to the survey made by JCRR****, comparing the double cropping of rice and inter cropping of vegetables between two crops of rice, the labour cost of the latter per hectare is more than 80 per cent larger than the former, while net return of the latter per hectare is 106 per cent higher than the former. In absolute figure, the net return of the latter is US$597 and that of the former is US$290. Besides labour, the latter farmers use more fertilizer, agricultural chemicals as well as more animal and mechanical powers. But the difference of costs of materials of the former and the latter management is not so large as labour.

This means that using more input materials or more cash expenditures to the former management, labour is more fully used, thus resulting in higher net income.

Because of its rapid industrialisation, the Republic of China is now facing the problem of shortage of labour, which Japan likewise experienced ten years ago. However, how to overcome the problem of labour shortage in Monsoon area which mainly depends upon rice growing is not so easy task, because enlargement of holdings or farm mechanization has various problems in such areas.

In this connection, it should be noticed that in Taiwan Province, the Republic of China the introduction of small tillers achieved a vital role in the intensification of her agriculture. Even in the small-scale farming under the condition of abundant labour, labour was short in the busy seasons. This was particularly true in Taiwan, because they grow rice twice a year. The small tiller was introduced to even the labour peak in the busy seasons, and the power of which was used for various purposes, too, including dehusking of paddy, pumping up water and even for transporting rice to the market. Labour thus saved was reutilised for other enterprises of the farms, such as mushroom or asparagus growing or pig raising which do not require much land. As mentioned earlier, labour in the slack season was used for vegetable growing. Thus Taiwan agriculture has been intensified. In such a way, the farming in Taiwan used not only a large quantity of fertilizer but also small type tillers to intensify the farming. Such investments required not only more cash expenditures but also more labour on the part of farmers with limited land area, thus enabling them to raise their income.

In this case, it should also be noticed that the mechanization itself was not so suitable for the intensive cultivation of vegetables, because the land was intensively used row by row, so that the operation of machinery, even though it was smaller one, was rather difficult.

In other words, in Taiwan farm machinery (mainly small tillers) has been effective for speeding up farm operation to enable double or more croppings rather than to save labour.

This prevents a new problem which emerged in Taiwan agriculture under the condition of shortage of labour, that is, whether or not farmers could change from multi-cropping farming to simple cropping farming, growing only one or two crops within a year, without decreasing their relatively high income being enjoyed by them at present from the former type of farming. In the latter case, the mechanization would contribute more directly to the saving of labour, if their size of farming could be enlarged.

(2) Problems of Changes in Cropping Patterns

The problem of crop diversification from the viewpoint of national economy is closely related to food supply and demand conditions in the countries concerned. Since the increased cereal production is being achieved rather successfully, the food as well as agricultural production pattern should be diversified, paying due attention to the change in food consumption pattern. This would be found in changes in demand for food in relation to the changes in income per capita of a country as mentioned earlier.

From the viewpoint of individual farmers or of farm management, the problem of crop diversification or changes in cropping patterns has such favourable conditions for farmers as listed below.

a) Equal distribution of seasonal labour, evening the peak and trough of labour in busy and slack seasons.
b) Dispersion of the risks of cropping caused by price fluctuation and unfavourable weather.
c) Fuller utilisation of land and family labour to maximise income of farmers, etc.

These conditions are particularly important in countries where pressure of labour to land is high. In short, from the national point of view, there is a problem of marketing of food as well as agricultural products at home and abroad. It is also closely related to the problem of comparative advantage of the cost of production of the crops in the countries concerned, if it includes foreign trade.

From the viewpoint of farm management, there is a problem of resource allocation, partly mentioned in the foregoing paragraph. So far, scarecity factors in agriculture in this region are land capital, and labour is an only factor which is abundant. It is, however, chaging always as indicated in the examples for the Republic of China and Japan.

Problems of diversification of agriculture both on national and individual basis, have other various economic, institutional and technological problems in this region, besides the problem indicated in the foregoing paragraphs. Also climatic conditions in Monsoon Asia should be considered. ■ ■

* Asian Productivity Organization (APO) is an inter-governmental Orgranization established in 1961 to encourage productivity improvement both in agriculture and industry. Member countries of APO are, Hong-Kong, India Indonesia, Iran, Japan, Korea, Nepal, Pakistan, The Philippines, Singapore, Sri Lanka, Taiwan Thailand and Viet-Nam.

* * "The State of Food and Agriculture, 1971", FAO, Rome, 1971.

* * * This rate seems to be too high, since the statistics compiled in 1950 is rather doubtful.

* * * * Chien-Pan Cheng, "Multi-cropping Practised on Paddy Field in Taiwan, PID-C-339 (R), November 1, 1971, p. 10.

Mechanization, Labor and Time in Multiple Cropping

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The multiple cropping project at the International Rice Research Institute is studying cropping systems that will allow greater intensification in the rice growing areas of Southeast Asia. In these new systems of food production certain factors become critical which were not of major importance in traditional cropping systems.

One such factor is timing of operations. In the traditional system of growing rice it does not matter if the farmer is 4 or even 6 weeks late in planting his rice. In a cropping system in which a farmer is planning to grow three or four crops in 1 year, planting dates are critical. A crop must be harvested and another crop seeded immediately if the farmer is to grow the crops at their optimum periods. The critical times in intensive cropping systems are harvesting and planting which usually occur within 1 or 2 days of each other. At present, there are few small scale implements for harvesting the variety of crops that a farmer might grow. But many machines are available for soil preparation and a few for seeding.

The labor utilization and subsequent production costs of intensive systems are directly related to the requirement for rapid field operations. The relative production intensity and the size of area a farmer can handle are thus determined by labor usage and availability. Substitution of tractor power for hand labor in an intensive system has a marked influence on these limiting factors as can be seen from the follwing data from an IRRI experiment.

The cropping pattern was started in August 1971 and was terminated in May 1972. Only chemicals and seeds which are locally available were used to make the cropping system as realistic as possible. In the cropping system the basis for making any decision was: Would the operation and the expense involved give a good return on the crop on which it was going to be used? Little consideration was given to the effect on the following crop. The experiment was laid out in plots 12m × 25m with the rows running along the 25m. Throughout the experiment, cost was kept to a minimum. This was particularly significant in regard to weeding. Each crop was fertilized individually and when two crops were grown together the fertilizer was simply added for each independently of the other crop. The crops were irrigated but no record of the water use was kept. We assumed that the farmer used a small six-horsepower Landmaster tractor only for soil preparation.

In the control of the experiment sufficient labor any one job was supplied to allow the operation to be finished withhin the day it we started. In the treatment wae assumed that a farmer with three man-equivalents available throughout the year had 1 hectare under an intensive cropping system. Assuming three man-equivalents and a 6-day week approximately 150 man-hours per week are available. Weeks 4, 14, 21, 26, 31 and 39 in **Figure 1** involved over 100 hours of labor per week and all but Week 4 used over 150 hours of labor per week.

If the farmer does not hire labor and uses only the hand tractor for soil preparation, he would be limited to 0.3 hectare with this labor use pattern. It is not likely that any farmer would choose this course of action. He would more likely choose a less intensive cropping system making more extensive use of his land. This less intensive use of his land would mean lower production per worker per unit of land. Throughout Asia as a whole, however, with the increasing cost of labor and rising demand for

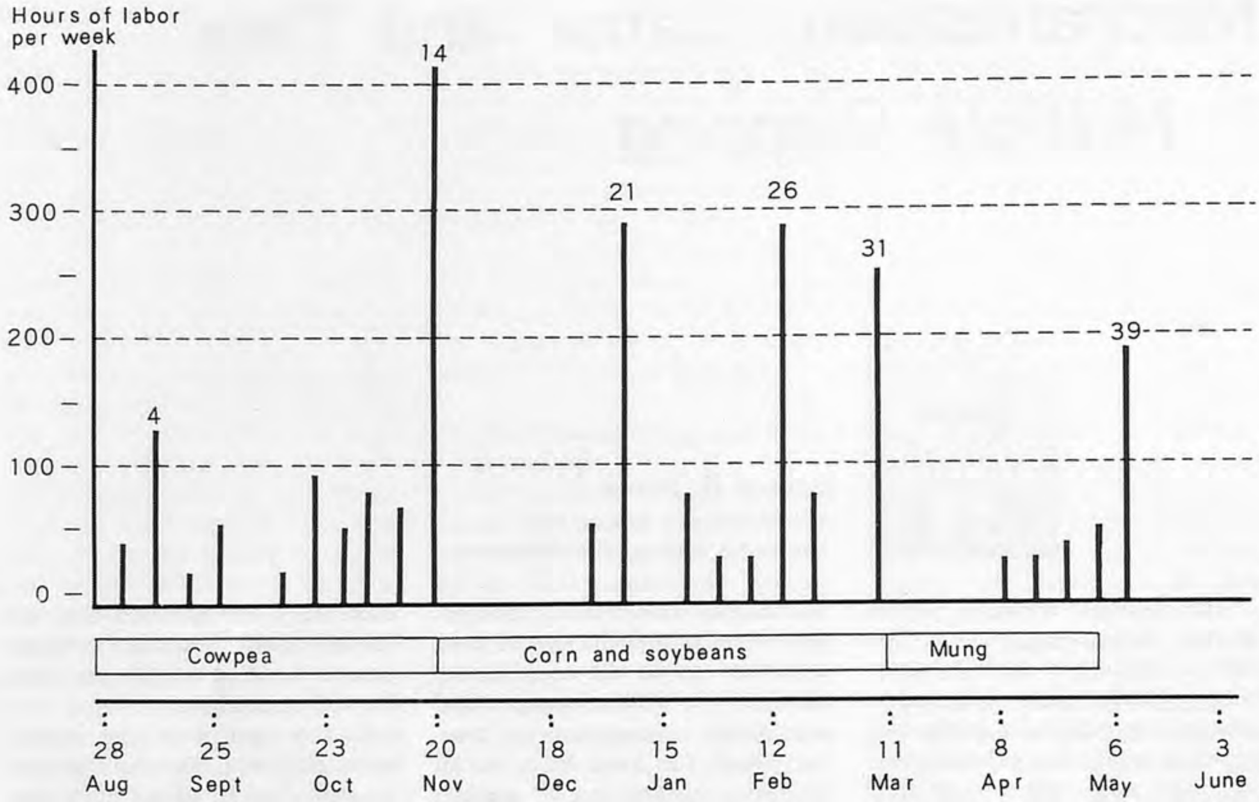

Fig.1 Original cropping system and labor requirements.

food, farmers will be forced to make more intensive use of land. Using the hand tractor more extensively in the cropping system described above the farmer can keep his labor requirements within the 150-hour limit for all weeks except Weeks 31 when he is harvesting two crops.

The revised tractor intensive system in **Figure** 2 shows the same cropping pattern, with exactly the same planting dates but with major change in the weekly labor requirements in the cropping system. The reduction in the peaks of labor results from using the hand tractor to do much of the work in peak periods. We assumed that the farmer can use his hand tractor whenever he need it.

The activities in the critical weeks are broken down into operations in **Table** 1. The major change from the original system to the revised system is that the hand tractor and a small seeder are used instead of planting by hand. In Week 26 the hand weeding which had taken 190 hours of labor can be done in 20 hours by the tractor. This weeding involves two passes with the tractor to get the weeds between the corn and soybeans. A single pass would require about 10 hours per hectare but would not be as thorough.

The original cropping system required 112 hours of tractor time for land preparation and 1,994 hours of labor. The revised tractor intensive system required an extra 72 hours of tractor time but required 640 hours less labor giving a total requirement of 1,354 hours per hectare. There is still a slight excess labor requirement in Week 31 when corn

Table 1 . Labor use in peak weeks.

week	Operations required (hours/ha) Original		Revised	
4	Hand seeding cowpea (Vigna sinensis L.)	127	Tractor seeding cowpea	13
14	Harvesting cowpea	112	Clearing vines with pods	120
	Clearing vines	112	Tractor seeding corn	13
	Hand seeding corn (Zea mays L.)	177		
21	Hand seeding corn	177	Tractor seeding corn	13
	Hand seeding soybeans (Glycine max L.)	65	Tractor seeding soybeans	15
26	Handweeding	190	Tractor cultivating	20
31	Harvesting soybeans	110	Harvesting soybeans	110
	Harvesting corn	62	Harvesting corn	62
	Hand seeding mung (Phaseolus Aureus Roxb)	34	Tractor seeding mung	13
39	Harvesting mung	74	Clearing mung vines with pods	120
	Clearing mung vines	108		

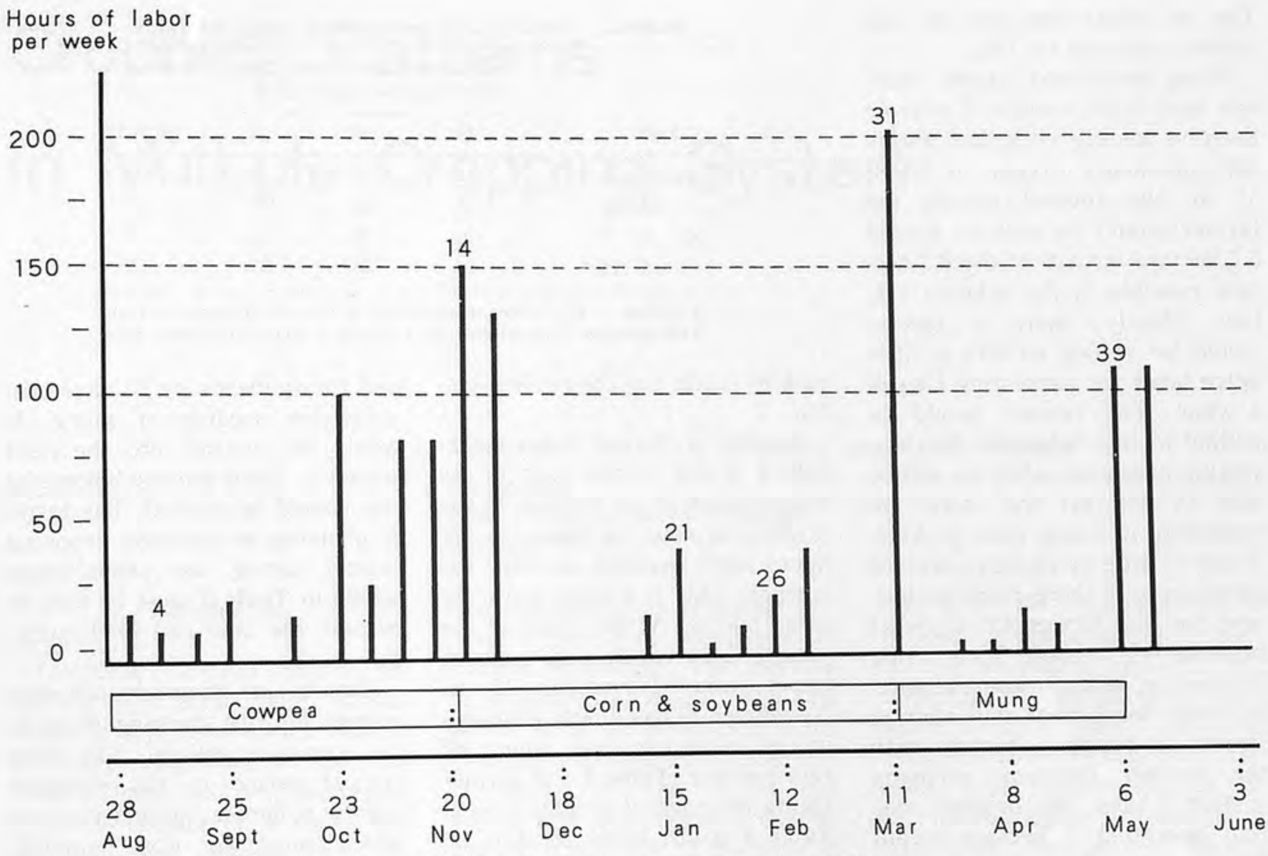

Fig.2 Revised cropping system and labor requirements.

Table 2. Return and expenses for a cropping system comparing 2 levels of labor and tractor use.

	Existing system		Revised system	
Total return		₱7,316		₱7,316
Expenses				
Seed chemicals	₱1,479		₱1,479	
Hand labor[1]	997		677	
Tractor[2]	560		920	
Total variable expenses		₱3,036		₱3,076
Net return		4,280		4,240
Net return/hour of labor		2.64		3.63
Net return/peso of cash expense		2.01		1.77

1) Labor valued at ₱0.50/hour
2) Tractor valued at ₱5.00/hour
Note: ₱1.00 = US$0.15

stover and soybeans are harvested. There does not appear to be any way to alleviate this pressure point with presently available attachments for small hand tractors.

The assumption that the hand tractor costs ₱5.00 per hour is not totally realistic for a farmer who owns his own tractor. The more hours he operates it the lower the fixed cost per hour of operation. There will be a standard operating cost for operator but the depreciation and repair will increase as the hours of use per year go up. With an additional crop of rice being grown which requires approximately 50 more tractor-hours a total of 234 tractor-hours per year would be required. It may not be economical for the farmer to own his own tractor unless he can also hire the tractor out to do custom work. But the farmer is unlikely to be able to use the tractor for custom multiple cropping work on other farmers' fields in the first planting after rice. The farmer will need all of his labor, management and tractor time to get his own crops seeded. No other farmer would want to count on having enough dry days in that period to wait for his crops to be planted after the tractor owner planted his upland crops.

The economics of the substitution of a tractor for hand labor is shown in **Table 2**. The net return from the original system and revised system is essentially the same. But, the difference in net return per hour of labor is considerable -- the farmer received 37% more in the revised system. Substitution of a hand tractor for labor also increased the cash cost of the revised system. An additional ₱360 cash expenses were incurred in the revised system.

The net return per peso of cash expense dropped by 12%.

Using the revised tractor intensive system the farmer is able to keep his weekly work load within 150 man-hours except in Week 31. In the revised system the farmer would be able to handle 0.7 hectare instead of the 0.3 hectare possible in the original system. Mostly likely a farmer would be willing to hire a little extra labor for harvesting I week a year. The farmer would be willing to hire labor for the harvesting operation when he will be able to pay off the labor immediately in either cash or kind. There is little or no risk involved as the crop is there ready to harvest and the farmer knows what price he will receive. Thus hiring 55 hours of labor or approximately 1 man for 1 week will allow a farmer to handle 1 hectare with the revised intensive cropping system. Under the original system operating 1 hectare meant hiring an additional 653 man-hours of labor or approximately 31 man-days in 6 different weeks.

The original system requires ₱1,580 of credit for 27 weeks to operate the total system. At an annual interest rate of 13% the cost of credit is ₱106.80. The revised system has a credit requirement of ₱1,940 for 27 weeks with a credit cost of ₱130.95 giving an increase of 22.6% in the cost of credit for the revised system.

Table 3. Probable and actual daily mean rainfall *

Date	Precipitation (mm) with probability equal or more than: 70	50	30	Actual
Nov. 16—23	14	30	54	16
24—30	28	56	101	17
Dec. 1— 7	10	26	55	6
8—14	14	23	37	37

* Wickham T. H. "Water management in the humid tropics: a farm level analyses," unpublished Ph. D. thesis. Cornell University. 1971.

Timing is critical when establishing a new upland crop in the rainy season in the tropics. In the original system, at Week 4, 127 hours were required to plant the cowpea. This is 5 days work for three people. At this time of the year 5 days rarely pass without heavy rain. November 16 to November 23 has a 50% probability of receiving over 30mm of rain per day (**Table 3**). A farmer facing the rainfall probabilities in **Table 3** is not likely to start an intensive cropping system which would require 5 days with no rain for planting. During our experiment November 15, 16 and 17 were dry and thereafter it rained for several weeks. If 5 days were needed to complete seeding it would not have been possible to seed that I hectare until December 20. Seeding would have been spread over 1 month. Delaying the planting of the sweet corn and the soybeans by 30 days prevents the seeding of mung. It would be too far into the next season to allow harvest before the rice should be planted. The farmer planning an intensive cropping system facing the probabilities shown in **Table 3** must be able to prepare the land and seed quickly.

Harvesting mung

Timing in intensive cropping system for rice growing areas in the tropics is critical. The most critical period in the intensive system is harvesting and planting which must be done quickly. Weeding and other operations rarely put a strain on the farmers' resources. This turn around time from one crop to the next is made up of harvesting, clearing the field, land preparation and planting. Machines are available for land preparation. There is little or no mechanization available for harvesting, planting, and clearing the fields on small rice farms. It is in these areas that mechanization can make its largest impact on intensive cropping systems.

A final, important point for consideration is the need for shifts in the cropping pattern as mechanization is adopted. As a farmer shifts from hand or animal power to more intensive tractor usage his cropping pattern will shift to permit more efficient use of his new power source.

■ ■

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Cropping Patterns in Multiple Cropping System

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Introductin

Cropping pattern symbolizes the ratio of area under various crops at a point of time. Thus, it warrants identification of the most efficient crops of the region which is considered a homogeneous soil and climatic belt, the rotation in which the crop fits in and also the intensity of cropping. Thus in nut shell, cropping pattern is made use of in a more comprehensive and pervading sense. It also implies cropping scheme and cropping intensity best suited for the farming. On the contrary, multiple cropping means growing of more than two crops on the same piece of land in one calendar year.

The cropping intensity will be largely dictated in such a sequence by the availability of irrigation facilities. In chronic moisture deficit areas there may be a wide spectrum of crops available for cultivation but the intensity in such a situation would be much less on account of the limitations of moisture. In these areas, fertilizer and moisture use efficiency hold paramount importance and can be greatly augmented through improved technology.

As indicated earlier, the identification of the most efficient crop and its knitting into a remunerative and practical cropping system is the basic ingredient of success in farming. The increase in population at an alarming rate almost in all the developing countries has necessitated to augment production per unit area, time and inputs. The Asian countries possess a bountiful endowment of nature viz., sunshine round the year, deep alluvial soils, great variety of edaphic conditions, climatological parameters and crops. However, the economic exploitation of the gifts of nature warrants tailoring of photo-and thermo-insensive varieties, improved agro-technology, scientific water management, balanced nutrition and suitable implements. In fact, cropping patterns for a multiple cropping sequence would be chemicalization and mechanization oriented, therefore, the availability of suitable chemicals and implements would be equally essential for attaining success in such an endeavour. This paper is an attempt to put together the available information on these aspects with a special reference to Indian conditions.

Cropping Systems and Patterns

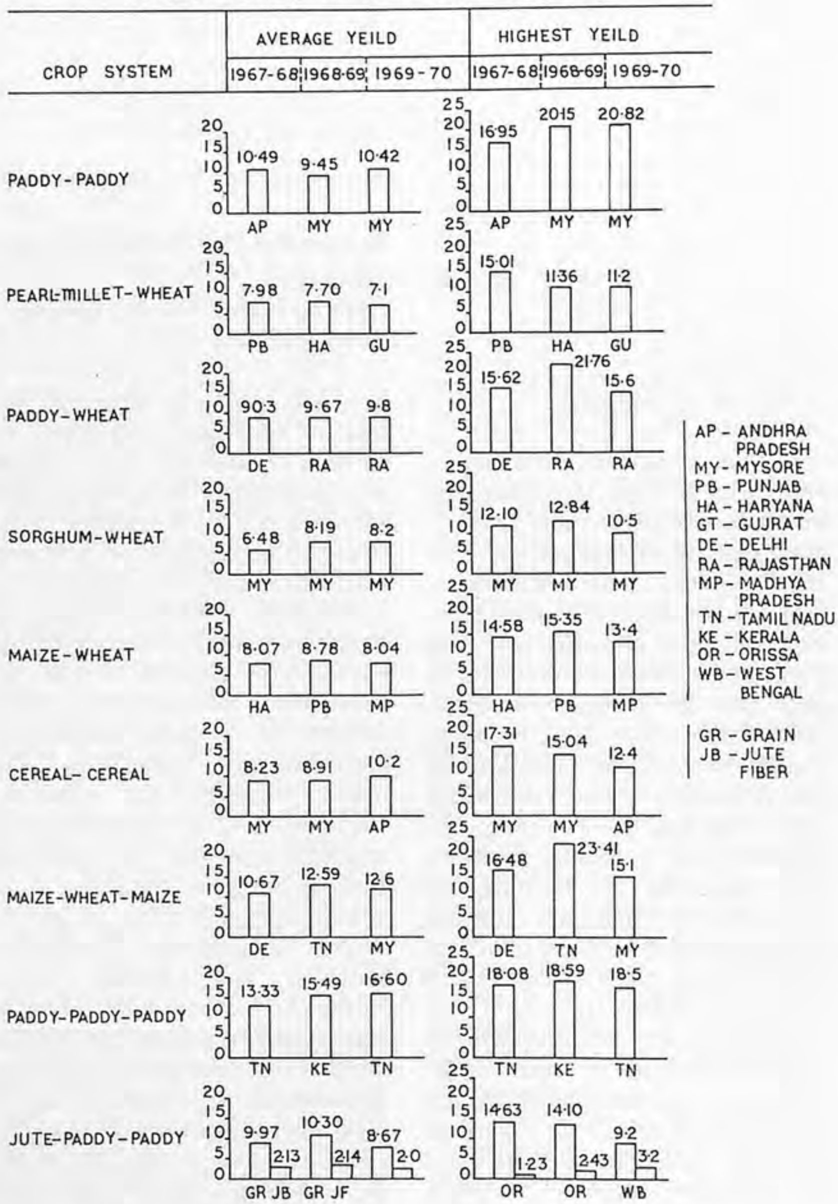
No single cropping system can have universal applicability and therefore the formulation of various cropping systems based on crop adaptabity and efficiency constitute the initial spade work before testing their suitability using economic returns as a yard stick. The performance of the proposed cropping systems can be augmented through the application of available management techniques and finally its acceptability by the farmers, the ultimate users is tested through appropriate extension agencies. The availability of resources viz. fertilizers, water, labour and managerial skill is a pre-requisite for choosing cropping systems. The following discussion throws light on various aspects of multiple cropping systems.

Areas of Assured Water Supply :

The cropping patterns for irrigated areas should be economically feasible and easy with operational point of view also. The efficient crop of a particular region should be knitted in the cropping systems intended for inclusion in the cropping patterns of that region locality. The Indian Council of Agricultural Research has carried out National Demonstrations on multiple cropping systems in different parts of the country. The cropping systems included in these demonstrations consisted of two

FIG. 1. PERFORMANCE OF VARIOUS CROPPING SYSTEMS IN NATIONAL DEMONSTRATION
1967-68-1969-70
(MULTIPLE CROPPING)
GRAIN YIELD (TONNES/HECTARE)

(REF. ANNUAL REPORT, ALL INDIA COORDINATED PROJECT ON NATIONAL DEMONSTRATIONS, 1969-70 AND RAINY SEASON 1970)



and three crops. The data obtained over a period of three years have been depicted in **Fig. 1**. A perusal of these data would reveal that 50 percent of 742 demonstrations conducted in different States in 1969-70 yielded more than 9.0 t/ha. In 82 percent cases the yields exceeded 7.0 t/ha.

The cropping systems consisted of two and three crops and a few of them are listed below.

Paddy—Paddy, Paddy-Weat, Maize-Weat, Pearl millet-Weat and Sorghum-Wheat.

The above systems involved cereals and millets. It has been reported that the mean yield in case of paddy-paddy system ranged from 4.66 to 14.68 t/ha. The All India Mean and the highest yields were 10.49 and 20.82 t/ha, respectively. The net return reckoned for three best farmers was approximately Rs. 7,000 per hectare per annum. Similarly, in paddy-wheat system, the performance was spectacularly attractive. The yield in the system varied from 3.2 (Madhya Pradesh) to 13.43 t/ha (Rajasthan). The returns varied from Rs. 7,000 to 8,000 per hectare per year. These demonstrations brought home a point that different cropping systems showed their suitability in different localities and therefore, the recommendations could be accordingly formulated. These results can be used to specify the cropping patterns for various agroclimatic regions of India to augment the production per unit area and inputs.

In the National Demonstration Project, two crop systems with millets and cereals were carried out in Andhra Pradesh, Mysore, and Tamil Nadu. In these systems the first crop was Pearl-millet/Maize/Sorghum/Finger Miller, while the second crop was Paddy/Pearl-millet/Maize/Finger-millet/Sorghum/Wheat. The highest average yield was obtained in Mysore (10.51 t/ha). Finger-millet-Finger-millet system was tested in Mysore State where this crop has proved to be the most efficient one. It has been reported that the mean yield was 7.88 t/ha.

Three crop rotations included in the National Demonstraions were as follows :

Paddy-Paddy-Paddy, Cereal-Cereal-Cereal. (Paddy-Pearl-millet / Maize / Sorghum / Finger-millet, Paddy/Pearl-millet/Maize-Wheat/green gram), Paddy-Paddy-Pulse and Maize-Potato-Wheat. In Orissa, Paddy-Potato-Paddy gave an excellent account and the mean yield was 12.29 t/ha grain and 16.68 t/ha tubers. Similarly, in Mysore Pearl-millet-Maize-Wheat rotation produced 16.02 t/ha. The results of these

Table 1 : Yield of individual crops in a four crops system at the Indian Agricultural Research Institute

System	Crop	Yield Q/ha				
		1967-68	1968-69	1969-70	1970-71	Mean yield
1	2	3	4	5	6	7
Green gram-Maize-Potato-Wheat	Green gram	10.0	11.0	14.0	9.0	11.0
	Maize	42.0	42.0	36.0	39.0	39.7
	Potato	206.0 (41.2)	213. (42.6)	220.0 (44.0)	150.0 (50.0)	222.2 (44.4)
	Wheat	44.0	38.1	40.7	40.4	40.8
Total production		**138.2**	**133.7**	**134.7**	**138.4**	**135.9**
Green gram-Maize-Brassica-Compestrisvar. Wheat.	Green Gram	10.0	8.0	12.6	9.0	10.1
	Maize	42.0	35.2	38.0	35.0	37.5
	B.compest-risvar.	8.0	7.0	8.5	9.4	8.2
	Wheat	27.8	23.0	24.0	33.4	27.0
Total production		**87.8**	**73.2**	**93.1**	**86.8**	**112.8**
Green gram-Maize(cobs)-Turnip-Wheat	Green gram	12.0	12.0	9.0	10.	10.5
	Maize cobs		100.0	80.0	–	90.0
	Turnip		250.0 (37.5)	270.0 (40.5)	–	260.0 (39.0)
	Wheat		42.0	44.0	–	43.0
Total production			**91.5** +100q/ha green cobs	**93.5** +80q/ha green cobs	–	**92.5** +90q/ha green cobs
Maize+Cowpea(F)-Maize-Sorghum(F)-Oats(F)	Cowpea(F)		380.0	398.0	376.0	384.6
	Jowar(F)		550.0	429.0	390.0	456.3
	Oats(F & G)		270.0 +15	340.0 +10	556.0 –	388.8 +12.5
Total production			+ 15(grain)	+ 10(grain)	+	+ 12.5(grain)
Green gram Maize(cobs)-	Green gram		12.0	19.0	12.0	11.0
	Maize(cobs)		100.0	80.0	90.0	90.0
	Radish		185.0 (27.8)	270.0 (40.8)	300.0 (45.0)	251.6 (37.8)
	Wheat		45.0	43.4	45.0	47.4
Total production			**84.8** +100 (green cob)	**92.94** +270 (green cob)	**106.0** +90 (green cob)	**96.2** +90 (green cob)

Source : Recent Research on Multiple Cropping, Indian Agricultural Research Institute, New Delhi, India, 1972(Res. Bulletin No. 8).
F=Fodder
G=Grain

demonstrations also revealed that the crop efficiency varies with locality and therefore, the tested cropping system included only the efficient crop of the region.

Four crop systems have been tested at the Indian Agricultural Research Institute, New Delhi and the data obtained over a period of four years has been reproduced in **table 1**.

Multiple Systems with Pulses

Protein mal-nutrition is a wide spread and baffling problem in India and other developing countries. The potentiality of pulses crops to fill up the void gap is undoubtedly great especially in India where most of the population is vegetarian. Another important characteristic of these crops is low water requirement. Therefore, their inclusion in the multiple cropping systems for limited water supply areas assumes an added dimension. A few multiple cropping systems have been developed and tested at the Indian Agricultural Research Institute and the results are highlighted below.

The cropping system tested was green gram, variety Pusa Baisakhi, which was grown from April to June. This was followed by red gram variety Pusa Ageti (a short duration cultivar) and black gram variety Type 9 was grown as an inter crop during July-September/November. Lentil variety 9-12 was cultivated from October - March / April which marked the completion of the system **(Fig. 2)**. The total pulse production from this system amounted to 5.03 t per hectare per year which amounted to 13.78 kg of pulse per hectare per day. The most important feature of this system is that it can be adopted in areas of limited water supply on marginal lands. This is, because the legumes are capable to fix the atmospheric nitrogen and also to improve upon physical conditions of the soil. The investigations are currently underway to test the various rainy season cereals and millets, winter season cereals and pulses viz. peas and gram in different adaptable combinations.

Cropping Systems with Vegetables

The vegetable growing community of India follow multiple cropping systems from times immemorial where the photosynthetic factory functions round the year. These farmers have adequate knowledge and water at their command. The application of heavy doses of manures and fertilizers maintains the fertility of the soils. Recently various multiple cropping systems have been evolved at the Indian Agricultural Research Institute New Delhi using the available scientific know-how. These studies have

	Systems	Net return (Rs/ha)
1.	Maize (fodder) turnip-Onion	3555
2.	Sorghum-radish-wheat	9270
3.	Radish-Onion-cauliflower	10,133
4.	Peas-spinach-tomato-okra	10,530
5.	Potato-radish bitter gourd-tinda	8,590
6.	Cauliflower + turnip-bringal + long melon-cauliflower + radish	11,640
7.	Cabbage + radish-tomato (seed) + onion-cauliflower + spinach	10,485

Source: Recent research on multiple cropping, Indian Agricultural Research Institute, New Delhi, Res. Bull. New Series No.8.

been aimed at putting the intensive cropping in vegetables on scientific footing. These cropping systems either involved only vegetable crops or various combinations with food grain and fodder crops. A few of these systems are given above.

As indicated above, a wide spectrum of common vegetable crops can be included in the multiple cropping systems under Indian conditions and elsewhere depending upon the availability of resources, managerial capacity, irrigation water and necessary equipment.

Besides boosting the returns, multiple cropping also generates employment opportunities. However, the employment potential varies with the cropping intensity. This has been graphically represented in **Fig. 3**. These data have been drawn from the work done at the Indian Agricultural Research Insitute, New Delhi. (Res. Bull. New Series No. 8).

Moisture Deficit Areas:

A wide variety of crops has been tested for its suitability and efficiency under dry land conditions at the Indian Agricultural Research Institute, New Delhi, India. The objectives of this test has been to grow two crops even under dryland conditions by coupling the improved agro-techniques with water conservation practices. The crops being tested in the dry land cropping cafeteria are given below :

Rainy season (Jul.-Sep./Oct.)

1. Hybrid pearl-millet (direct fown and transplanted, HB 3)
2. Local sorghum (Fodder)
3. Green gram (Type 1)
4. Castor beans, (Aruna)
5. Soybean (Bragg)
6. Red Gram (AS 5)
7. Black Gram (Type 9)
8. Cowpeas (fodder)

Winter season (Oct./Nov.-Feb.-/Mar.)

1. Mustard, (BSH i)
2. Barley (Ratna)
3. Tarmira *(Eruca sativa)*

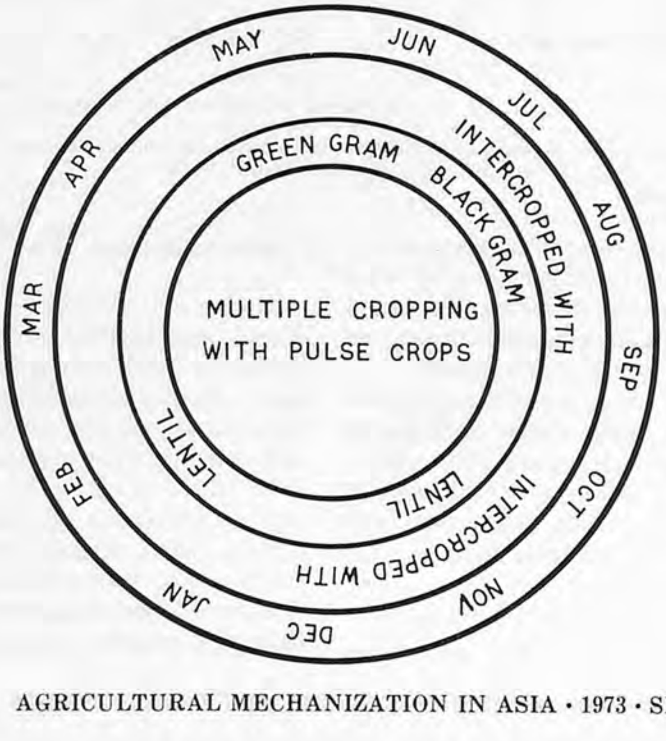
It has been observed that transplanting of pearl-millet on ridges provides adequate space for conservation of rain water in the furrows which can be successfully made use of to grow a crop of mustard.

It has also been observed at the Institute that in case of late onset of monsoon, pearl-millet can be successfully transplanted on any rainy day. The senior author has observed that a transplanted crop of pearl-millet (HB 3) could be matured on about 220 mm of rainfall received after transplanting. This opens up a new possibility to test this practice in relation to multiple cropping under dry land conditions. The rains received towards the end of the rainy season can be conserved in the soil which in turn would be utilized to grow a crop like mustard in the winter season. However, these are the observations whch are still in the process of investigation.

Plant Types and Varieties:

Photo and thermo-insensitive plant types are necessary for their inclusion in the multiple cropping systems. It is illustrated

FIG.2. PULSE CROPS BASED MULTIPLE CROPPING SYSTEM TESTED AT THE INDIAN AGRICULTURAL RESEARCH INSTITUTE NEW DELHI (INDIA)



by the evolution and introduction of the dwarf wheat varieties like Sharbati sonora (amber grain) and Sonolika which can be planted as late as December or middle of January. Agronomy for late sown wheat has also been worked out. This has made it possible to grow a crop of potato after maize. Therefore, the varieties which can be grown under a wide spectrum of agro-climatic and edafic conditions is a basic necessity for multiple cropping systems. The efforts at the Institute had led to the evolution of a series of crop varieties which can be very successfully knitted into the multiple cropping systems.

Besides vegetables and pulses forage crops have also been tested in multiple cropping system. In a few cases inter-cropping of various forage crops has been investigated at the Institute. The results from the studies have been very impressive and of high economic value. These studies have revealed that any set of crops to commensurate with the needs of the locality of the farmer can b knitted in a multiple cropping system which can be recommended later on as a cropping pattern for the locality as a whole. Four of the many multiple systems have been quoted below.

The carrying capacity of the different extensive systems has also been investigated.

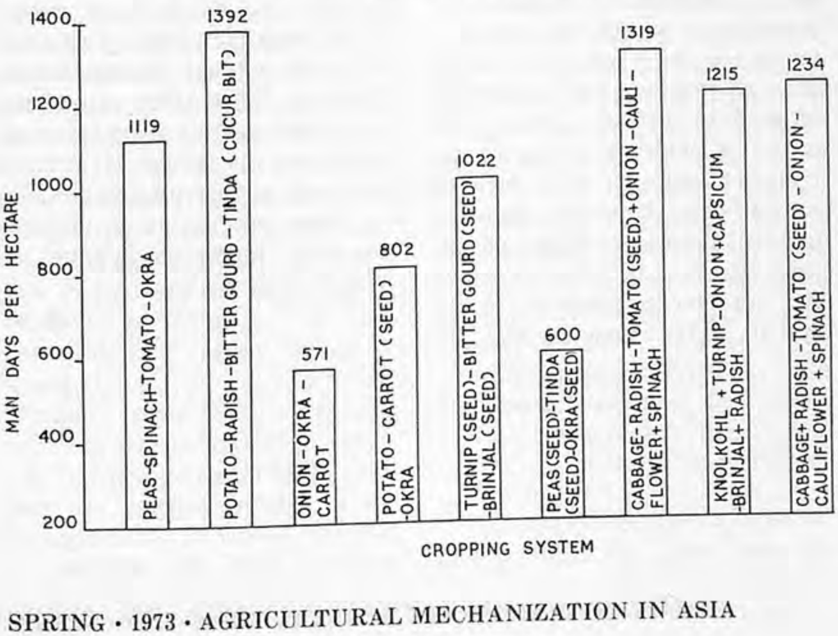
Table 2: Soil test values before and after pearl-millet and Wheat.

	Item	N	P	K
1.	Soil test values prior to sowing of hybrid pearl-millet No. 4	230.4	33.3	271.0
2.	Calculated soil test value after harvesting 53.2 q/ha of pearl-millet with 90 Kg N, 26.2 Kg P and 250 Kg K/ha.	183.2	26.1	134.6
3.	Soil test values experimentally obtained after harvest of pearl-millet.	184.4	26.6	153.6
4.	Calculated soil test values after Wheat (Sharbati sonora) 60 g/ha with 114.2 Kg N, 6.77 Kg P and 80.04 Kg K/ha.	322.8	22.1	198.6

	Systems	Green fodder (t/ha)	Net Returns (Rs/ha)
1.	Three crops of maize+ cowpeas-Oats+vicia	170.00	4,500.00
2.	Pearl-millet-maize+cowpeas-brassica-Oats+vicia	182.00	4,550.00
3.	Cowpeas-sorghum-berseem+oats	205.00	6,100.00
4.	Two crops of pear-millet+sorghum +teosinite-berseem+oats	245.00	7,200.00

FIG.3. EMPLOYMENT POTENTIAL OF VARIOUS MULTIPLE CROPPING SYSTEMS TESTED AT THE INDIAN AGRICULTURAL RESEARCH INSTITUTE NEW DELHI (INDIA)

(REF. I.A.R.I., NEW DELHI. NEW RES. SERIES NO. 8)



Fertilizer Use:

Use of adequate and balanced nutrition is a basic ingredient of success in multiple cropping. The fertilizer schedule for a cropping system is worked out by taking into account the available nutrients in the soil after the harvest of preceding crop. The equations have been developed at the Indian Agricultural Research Institute, New Delhi to estimate the fertilizer needs of the individual crop in a multiple cropping system and it is accomplished with the help of regression analysis. The values so obtained have been tested for applicability also. The values for pearl-millet-wheat system for Indo-Gangetic plains of Panjab, Haryana, Northern Rajasthan, Delhi and Western Uttar Pradesh **(Table 2)** have recently proved beneficial.

This exemplifies that the crops in a system should be adequately fertilized and residual effect if any should be worked out by regression analysis. The foresaid technique can be made use of in all kinds of intensive cropping system under a defined set of edhapic conditions. Besides fertilization schedule the microbial and physico-chemical aspects of soil have also received sufficient attention at the Institute. This may be pointed out here that adequate nutrition usually arrests soil productivity deterioration. A practitioner of multiple cropping system should always be vigilant since intensive cropping may warrant the nutrients which might have not displayed discernible response in the recent past. An example of this kind noted under Indian condition is the response of wheat variety Kalyan Sona to application of zinc.

Water Use:

The success in multiple cropping is largely dictated by the availability of irrigation water. The scheduling of irrigation for individual crops is to be done based on the standing recommendations for the locality concerned. However, the objective in multiple system is that each unit of applied water should bring about the maximum return meaning thereby its high efficiency. The investigations are in progress to work out the irrigation schedules and frequencies for the multiple cropping system under different agro-climatic conditions under the auspecies of the coordinated project on New Cropping Patterns and Water Use. However, the water requirement of individual crops in relation to depth of water table and its fluctuations round the year should be taken into account to recommend a cropping pattern involving multiple cropping system for a region. This has been taken care for while formulating four crops rotation viz. maize-potato-wheat-green gram. The crop of green gram is grown during the summer months which is a period of very much limited water supply and the crop has low water requirement, that is, can be grown by two irrigations only. The high yielding varieties which respond spectacularly to fertilizer possess high harvest index and hence the production per unit of applied water is more than local cultivars. Therefore, their inclusion in the intensive cropping patterns would highly augment water use efficiency.

Soil Physical and Chemical Properties:

Soil is a universal medium for crop growth and warrants proper maintenance of physical, chemical and microbiologiacl properties to sustain high levels of production. The multiple cropping system puts an extra draft on the soil and therefore, it becomes all the more essential to pay due attention towards the maintenance of the above soil characteristics to keep it permanently productive. As indicated earlier, adequate fertilization would encourage better root growth which will result in addition to a comparatively large quantity of organic matter to take care partially for the physical properties of the soil. This has been observed that high status of nitrate nitrogen in the soil inhibits the activities of the micro-flora namely the nitrogen fixing bacteria. Therefore, it appears imperative to search for the bacterial species which can operate even at medium and high levels of nitrate nitrogen. This is because, in multiple cropping system the inclusion of legume is basically to improve upon the physical properties of soil on one side, while on the other to curtail the fertilizer requirement of the system. It is expected that the research in progress at the Indian Agricultural Research Institute, New Delhi, would lead to the identification of the species which can operate even at high levels of nitrate nitrogen.

Mechanization:

Time plays a commendable role in multiple cropping systems. In a four crops system like maize-wheat-potato-green gram, there is a very short span of time available for the seed-bed preparation after the harvest of maize for timely planting of potatoes. It appears that suitable implements should be developed and the operation should be mechanized so that no time is lost. Any delay in such a time-tight schedule will adversely reflect upon the performance of individual crops and the system as a whole. Similarly, there is a very short time available for land preparation after digging potatoes for seeding wheat. This operation can also not be accomplished, without mechanization. The experiments carried out in Northern India in multiple cropping systems have brought out that the cropping intensity cannot be increased beyond existing level without the help of full or partial mechanization of the agricultural operations. The studies are also in progress to quantify the employment potential of multiple cropping systems with and without mechanisation. However, the authors are of the view that partial mechanization for timely operations is a basic need and an essential ingredient to attain success in a multiple cropping system on a small as well as large scale.

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Green Revolution through Multiple Cropping in INDIA

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Whereas the high yielding varieties of cereals, particularly wheat and rice, have been the catalysts that have ignited the green revolution, chemical fertilizer has been the fuel that has powered its foreward thrust. India is richly endowed with resources, such as favourable temperature and abundant solar energy for crop growth all the year round. Introduction and development of high yielding, short duration, photo-insensitive, fertilizer responsive varieties of crops have enabled the intensification of multiple cropping practices by providing greater opportunity for the selection of crops and varieties as well as adjustment of planting dates, leading to high yields per unit area per unit time. Chenmical fertilizers are an integral part of the crop production process and play a critical role in enabling the high yielding varieties to achieve their full potential. The green revolution would have remained a plant breeder's dream without adequate application of balanced fertilizers.

It is now firmly established that the biggest single breakthrough came in wheat with the introduction of high yielding varieties. Without being accused of being over-optimistic, it is safe to say that we will achieve in the next 2 to 3 years, similar results with rice, pulses, oil-seeds and some cash crops. The quick spread of high yielding varieties and the fantastic 7-fold increase in consumption and 5-fold increase in production of chemical fertilizer during the past decade accompanied by increased irrigation facilities and mechanization have helped in making the green revolution a reality.

In addition to perfecting the agronomy of individual crops, a great deal of emphasis during the last 4 years has been on developing intensive cropping systems to increase the productivity of land. The Government of India, State Governments, the Indian Council of Agricultural Research and the Agricultural Universities have conducted extensive research to develop improved agronomic practices, with emphasis on multiple cropping. With the help of extension agencies the results of this research has been taken to farmers' fields in an incredibly short time.

The success of events may be judged from the fact that the food grain production in the country has risen from 48 million tonnes in 1948-49 to 108 million tonnes in 1970-71, our target for 1973-74 being 120 million tonnes. The growth of domestic fertilizer industry also has been considerable. The consumption of fertilizer has risen from 0.29 million tonnes of nitrogen in 1960-61 to 2.1 million tonnes in 1970-71, but it has not risen at a rate which is considered essential for achieving the targets of agricultural production. Some of the prospects and limitation of increasing productivity through multiple cropping have been traced in this paper.

The prospects of attaining high yields with adoption of modern technology

India has a wide range of soil and climatic conditions and cropping patterns vary widely differnt from region to region and, to a lesser extent, from one year to another. The adoption of suitable package of practices for a particular cropping system is more important than development of package of practices in a given

Table 1. Year-wise production potential of 2, 3 and 4 crop sequences at I.A.R.I., New Delhi (1967-68 to 1970-71).

Yield (Q/ha)

Crop sequences	Crops	1967-68	1968-69	1969-70	1970-71	Mean
Maize-Wheat	Maize	42.0	46.0	38.0	35.0	40.2
	Wheat	45.0	57.4	47.0	50.0	49.9
Total Production		87.0	103.4	85.0	85.0	90.1
Moong-maize-wheat	Moong	10.0	9.0	12.6	9.0	10.1
	Maize	42.0	46.0	38.0	35.0	40.2
	Wheat	44.8	48.0	47.0	50.0	47.4
Total Production		96.8	103.0	97.6	94.0	97.7
Moong-maize-potato-wheat	Moong	10.0	11.0	14.0	9.0	11.0
	Maize	42.0	42.0	36.0	39.0	39.7
	*Potato	206.0	213.0	220.0	250.0	222.2
		(41.2)	(42.6)	(44.0)	(50.0)	(44.4)
	Wheat	44.0	38.1	40.7	40.4	40.8
Total Production		138.2	133.7	134.7	138.4	135.9

*Potato produce has been converted into 20% dry matter production.

crop. For instance, phosphatic and potassium fertilizers are not utilized fully by the crop to which it is applied. A considerable proportions of these elements remain in the soil to be utilized by succeeding crops. Consequently, fertlizer practices have to be developed more with regard to a particular cropping system. Techniques such as relay cropping, inter-cropping, mixed cropping, minimum tillage, weed control, residue and fertilizer management will not only reduce the cost of cultivation but will also sustain high level production over a period of time. Scientific multiple cropping can actually result in increased soil productivity by improving the physical, chemical, microbiological properties of the soil and increasing the fertility status.

The late Dr. S.S. Bains and his associates have investigated crop production potentials by adopting relay cropping techniques at the I.A.R.I. (Indian Agricultural Research Institute), New Delhi, on alluvial soil, from 1967-68 to 1970-71. A four-crop, single-year rotation of moong-maize-potato-wheat which gave a consistent yield of 13 to 14 tonnes of grain year after year as shown by the data in **table 1.** In this table, the yields of 2, 3 and 4-crop, single-year rotations have been presented for individual years during the past 4 years together with the mean yields over 4 years. On an average, two-crop rotations, such as maize-wheat, yielded approximately 90 quintals/ha. By introducing a pulse crop during summer months, after the harvest of wheat and before the maize crop is sown, the yield potential was increased by approximately 7 quintals/ha. When a fourth crop of potato was introduced after maize, the total production shot up to 136 quintals/ha as compared to that of 98.0 quintals /ha with three crops and 90 quintals/ha with two crops. With the adoption of modern technology, the production has remained more or less stable over the past 4 years in all crop sequences. Soil productivity, therefore, has remained constant over the years though there were slight fluctuations in yield total due to seasonal variations beyond the control of the producer. This shows that, with the selection of appropriate varieties of crops in a given sequence, optimum inputs of fertilizer, water and good cultural practices such as date of sowing, seed rate, depth of sowing, plant protection measures, weed control, etc. there is no apprehension of any deterioration of soil productivity. On the contrary, there is a tendency to build up the productive potential of land over the years.

Production potential in different States

Under the national demonstration scheme of I.C.A.R. (Indian Council of Agricultural Research), work on multiple cropping on the farmers' holdings has been in progress during the past 4 years **(table 2).** It can be seen that, when production potentials are compared irrespective of location, among the two-crop rotations, rice-rice rotation has given the highest average yield of 104.2 quintals/ha followed by rice-wheat with 98 quintals/ha and sorghum-wheat with 81.6 quintals/ha. Maize-wheat rotation followed jowar-wheat closely and bajra-wheat gave the lowest yield. Three consecutive crops of rice have given a total production of 165.7 quintals/ha while rice-rice-pulse gave a total production of 127.4 quintals/ha. A sequence of maize-potato-wheat gave a total yield of 66.4 quintals/ha of grains and 252.1 quintals/ha of potato. The rice-wheat rotation has proved to be very efficient in the north and north-western part of the country. A total production over 100 quintals/ha has been obtained in on-farm demonstrations in Rajasthan, Uttar Pradesh, Himachal Pradesh, Haryana and Punjab. In the south and south-eastern parts of the country where the winter temperatures are higher, rice followed by rice has given very high yields. In the States of Rajasthan and Gujarat sorghum followed by wheat has yielded over 80 quintals/ha and similar yield figures have been obtained maize followed by wheat in Bihar, Gujarat, Haryana, Himachal Pradesh, Mysore, Madhya Pradesh, Punjab, Uttar Pradesh and Maharashtra. Bajra followed by wheat, with yields ranging from 70 to 90 quintals/ha, has been found to be profitable in Gujarat, Punjab, Rajasthan, Uttar Pradesh and Haryana. In situations where it has been possible to grow three crops in a calendar year, three crops of rice have produced over 150 quintals/ha in the southern States of Kerala, Tamil Nadu and Mysore. The introduction of a pulse crop between two rice crops has resulted in a total yield of 124 quintals/ha of grain in Orissa. Maize followed by potato and then wheat can be expected to give an average yield figure of about 70 quintals of grain and 250 quintals of potato per hectare per year in the northern areas including the States of Haryana, Punjab, Rajasthan and Uttar Pradesh.

The All India Coordinated Agronomic Experiments Scheme (AICAES) of ICAR also has been conducting a production potential experiment at 44 different locations throughout the country which represent 17 major soil groups and 19 agro-climatic regions. Some of the multiple crop sequences tested during the year 1970-71 under the AICAES along with production data are presented in **table 3.** These results indicate that under the varying soil and climatic conditions, yields of the order of 100 to 150 quintals/ha can be easily obtained with proper soil and crop management. Thus, the evidence so far shows that in most parts of India soil and climate are no barriers to crop production levels of 10 to 15 tonnes of cereal grain per hectare per year, provided irrigation is available. Moreover these production levels can be sustained over the years with appropriate soil and crop management.

Table 2. State-wise mean production potential (Q/ha) of multiple cropping sequences (National Demonstrations 1969-70)

State	Rice-Rice	Rice-Wheat	Maize-Wheat	Bajra-Wheat	Jowar-Wheat	Ground-nut-Wheat	Rice-Rice-Rice	Rice-Rice-Pulse	Maize-Potato-Wheat
Andhra Pradesh	124.0	93.3	67.8	—	—	19.5+ 36.0	—	156.6	
Bihar	—	87.5	86.7	—	—	—	—	—	
Gujarat	—	92.5	82.6	80.0	84.8	31.2+ 53.0	—	—	
Haryana	—	106.5	88.2	91.3	—	—	—	—	92.2+ 416.0
Himachal Pradesh	—	107.0	80.8	—	—	—	—	—	
Jammu and Kashmir	—	99.5	64.4	—	—	—	—	—	
Manipur	—	68.2	—	—	—	—	—	—	
Mysore	146.8	92.9	84.6	69.3	74.0	18.1+ 15.0	148.0	100.8	
Madhya Pradesh	—	78.2	88.5	37.6	78.1	—	—	—	
Punjab	—	105.4	88.1	78.0	—	—	—	—	57.12+ 276.0
Rajasthan	—	145.7	77.9	78.4	99.0	30.8+ 53.9	—	—	33.0+ 160.50
Uttar Pradesh	—	107.5	90.0	87.7	82.7	34.0+ 53.7	—	—	76.2+ 150.8
West Bengal	—	87.1	—	—	—	—	—	—	
Delhi	—	—	52.7	—	—	—	—	—	
Maharashtra	91.6	—	93.0	46.4	73.6	—	—	—	
Kerala	100.2	—	—	—	—	—	179.9	—	
Tamil Nadu	119.8	—	—	—	—	—	169.2	—	
Orissa	97.9	—	—	—	—	—	—	124.8	
All India	104.2	97.9	80.4	71.1	81.6	26.8+ 42.3	165.7	127.4	66.4+ 252.1

Soil fertility changes due to multiple cropping

The question of how long the high levels of production can be sustained without loss of soil productivity is a vital one. Any crop production practice which would lead to a gradual decline in the productive capacity of the

Table 3. Production potential of different multiple crop sequences under varied soil types and climatic conditions in India (MAES-1970-71)

Experimental Centre	Soil type	Climate	Crop Sequence	Yield Q /ha
Tirupati	Red loam	Slightly dry very hot	Rice-Rice-Rice	143.7
B. H. U.	Alluvial	Slightly dry hot	Rice-Rice-Wheat	130.8
Maruteru	Medium black	Dry very hot	Rice-Rice-Rice	122.5
Kathulia Farm	Mixed red+black	Slightly moist mild	Maize-Wheat-Gram	147.0
Bhavanisagar	Red sandy	Dry hot zone	Rice-Rice-Maize	132.5
Rudrur	Medium black	Slightly dry hot	Rice-Wheat- Green Bean	100.6
Bichpuri	Alluvial	Dry mild	Bajra-Wheat-Green Bean	109.3
Pantnagar*	Tarai soil	Wet mild	Maize-Mustard-Maize	150.6
Cuttack	Alluvial	Slightly moist hot zone	Rice-Potato-Rice	102.7+ 153.3 (Potato)

*1969—70

soil, and hence production, should be avoided. The effect on the soil of continuous intensive cropping for extended periods of time, therefore, need careful study. Causes of any deterioration in soil productivity have to be identified so that corrective measures can be evolved. Since this necessarily involves long term studies data on this aspect are still meagre, although they are being built up continually.

Investigations carried out at Cuttack, for instance, on a sandy loam alluvial soil have revealed the changes in some of the physical and chemical properties of the soil due to multiple cropping.

Intensive cultivation had a deteriorating effect on soil structure. There was decrease in organic carbon content of the soil in all cropping patterns, the maximum decrease being noticed under continuous cultivation of rice. In soils where farm yard manure had been applied, there was a higher percentage of water stable aggregates.

Total nitrogen decreased in all cropping patterns after the completion of one annual cropping cycle. After two cycles it was noticed that there was no appreciable additional change in crop sequences like potato-rice-rice maize-rice-rice and groundnut-jute-rice, but a further fall was noticed in rice-jute-rice and rice-rice sequnces.

There was a slight increase in total phosphorus after each cycle in all cropping patterns except that when rice was followed by rice there was no change at the end of the second cycle. The extractable phosphorus of the soil increased after rotations like potato-rice-rice and maize-rice-rice, whereas there was no change in groundnut-jute-rice. There was decrease in other cropping patterns.

The total and exchangeable potassium status of the soil decreased after each annual cycle in all cropping patterns. The soil

Seeds arranged to show the sequence of four crops a year in ***relay cropping*** which is modified multiple cropping technique envolving the sowing of the succeeding crop before the harvest of the standing crop.

PH decreased in all cases after each cycle. The maximum decrease was noticed in treatments receiving inorganic fertilizers alone.

In evolving multiple cropping practices it is extremely important to construct cropping systems in which the requirements of individual crops ensures the efficient utilization of available nutrients in the soil. From the point of view of phosphorus utilization, rice followed by wheat is such a rotation.

Rice utilizes phosphorus in the form of aluminium phosphate whereas wheat takes up iron phosphate from the soil. The continuous submergence of rice fields helps in increasing the soluble iron phosphate whereas the wheat crop leaves residual aluminium phosphate for utilization by the succeeding crops of rice.

This complementarity, thus, leads to a very efficient utilization of soil phosphorus. There is also evidence that the available zinc status of soils increases after rice. Ramamoorthy has shown further that rice and wheat require specific soil nitrogen constituents for their best growth. Rice uses amino-nitrogen while the best source for wheat is hexoseamine. Utilizing such knowledge it is possible to manage soils to give maximum (optimum) yield of different crops. For example, incorporating residues of lequmes like cowpea and moong, which are relatively in hexoseamine content, into the soil would result in conditions specifically suited to rice cultivation. As well as the form in which crops take up various nutrients, the actual amount of available nutrients necessary for efficient growth has important implications in soil and fertilizer management. Thus, an optimum build up of 346 kg/ha of soil potassium has been determined for the rice variety Padma and 145 kg/ha for bajra Hybrid H.B. 4.

Table 4. Cost/benefit analysis of 2, 3 and 4-crop sequences

Crop sequence	Cost/ha Rs.	Gross income/ ha Rs.	Net return/ ha Rs.	Net return/ Rupee invested Rs.
Maize-Wheat	2189	7604	5414	2.47
Green Bean-Maize-Wheat	2570	8964	6394	2.49
Green Bean-Maize-Potato-Wheat	4177	14894	10961	2.62

Table 5. Employment potential of different crop sequences

Crop sequence	Crop	No.of man days/crop/ha	Total man days per rotation/ha	% increase over double cropping
Maize-Wheat	Maize	76	181	—
	Wheat	105		
Moong-Maize-Wheat	Green Bean	92	273	50
	Maize	76		
	Wheat	105		
Green Bean-Maize-Potato-Wheat	Green Bean	92	433	140
	Maize	76		
	Potato	160		
	Wheat	105		

Economics of Multiple Cropping

Not only production, but also the net return per hectare is considerably increased by intensive agricultural practices such as multiple cropping. Furthermore, since it is labour-intensive, it is a way by which the small holder with limited land but high labour resources, i.e. family labour, can raise his income to a reasonable level. Multiple cropping, therefore, does not only lead to greater income per unit area cultivated, but can also lead to a more equitable distribution of income and more employment opportunities. Of course, since the higher levels of productivity also require greater input, the amount of capital and other resources required on the part of the cultivator are also higher. The extent by which economic returns can be increased obviously will vary with the resources available to the cultivator, the cost of inputs, prices of agricultural products, market opportunities and so forth. It is, therefore, difficult to give general estimates of the increased profits per hectare possible with new crop technology. The following cost-benefit analysis of two-, three- and four-crop sequences grown at IARI, New Delhi, details of which are presented in **table** 4, gives some idea of the economics of multiple cropping.

A maize-wheat rotation resulted in a net profit of Rs. 5,414 per hectare with a net profit of Rs. 2.47 per rupee invested. By introducing crop of moong in the maize-wheat rotation was obtained a net profit of Rs. 6,315 per hectare and Rs. 2.49 net return per rupee invested. The four-crop single year rotations, namely, moong-maize-potato-wheat gave a net return of Rs. 10,961 per hectare or Rs. 2.62 per rupee invested. This then gives an example of the extent to which economic returns per unit area of land can be increased by adopting intensive agricultural practices and utilizing the best crop technology available. There is no doubt that as improved varieties of rice, oilseeds, pulses and cotton become available and our knowledge of the agronomy of these crops increases, immense possibilities for further increasing production and profits will open up. The so-called green revolution in wheat already has set the example for similar resolutions in other important agricultural field crops. To obtain high, sustained productivity levels it will be necessary, however, to develop scientific practices of management for entire cropping systems.

Employment potential in Multiple Cropping

For some years to come, most of India's rapidly increasing work force will have to be absorbed in agriculture. Multiple cropping, because of its labour-intensive

Relay cropping—Four crops with *toria* (oil seed) and potato practices, has been hailed as a means of providing employment to millions who are at present either unemployed or under employed. Some attempts have been made to estimate the magnitude of the employment potential as a result of various multiple cropping practices. The data presented in **table 5** are from the studies at IARI referred to earlier and give estimates of the labour required to grow two, three or four crops in a single year. By increasing the number of crops grown per year from two to three with the introduction of a moong crop in a maize-wheat rotation the labour input per hectare was increased by fifty percent. With the introduction of a potato crop as the fourth crop, the employment potential increased by way of 140% over that of double cropping. If one considers the number of hectares which eventually can be brought under multiple cropping in this country, these figures do indeed indicate that there is considerable scope for providing additional employment through multiple cropping.

Limitations to green revolution

However, these advantages can offset the benefits accruing from multiple cropping as illustrated in the above three examples, if we do not recognize the limitations of multiple cropping without developing a full crop production potential technology for a given cropping system. Long term changes in soil properties and build-up of pests and diseases in a continuous intensive cropping, lack of information on production physiology, use of machinery in the multiple cropping programme, fertilizer needs for a given cropping system (direct, residual and cumulative effects of various fertilizers for fixed crop system) and timings for critical farm operations need serious attention since technology and marketing opportunities keep on continually changing. If the green revolution has to be sustained over the years, a continuous generation of research data on the points enumerated above is of extreme importance. In this case it may be illustrated that wheat revolution has taken place by adopting a suitable package of practices for this crop. With the demand for increased food production and intensive cultivation programme, development of package of practices for rice-rice, rice-wheat, sorghum-wheat, maize-wheat, pearl millet-wheat, groundnut-wheat, cotton-wheat, rice-rice-rice and rice-rice-potato, maize-potato-wheat, two or three crops single year crop sequences along with the cost benefit ratios accruing to the farmers and the ultimate changes in soil productivity are of immediate need.

Moong Baisakhi (green bean)—An ideal inter-crop with sugarcane, cotton and *arahr* (pigeon pea)

Some basic needs for sustaining green revolution

1. In order to be able to apply the modern scientific crop production technology, proper water control needs to be developed under farmers' conditions for example this can be suitably adopted by restoring first to flood control in Bihar and Orissa.

2. If productivity has to be sustained, high level of production which ruins the soil and eventually leads to decreased productivity is not desirable. Hence there is an urgency to know more about management of cropping system.

3. Inputs and market opportunity have to be made available within the easy reach of each cultivator.

4. Unless the population growth is controlled and the productivity per individual is increased it will not lead to a better life for people but only to subsistence agriculture at a higher level of production. ■ ■

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Agricultural Diversification and Development

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Introduction

Infusions of the new technology into traditional agriculture are gaining dramactic results in Southeast Asia. Several countries in this area have begun shifts in production, as strategic moves toward agricultural development. There is spreading optimistic belief that the transformation is already sufficient to lift away the spectre of famine and to postpone, at least, the materialization of the Malthusian trap.

These gains have been most notable in basic food grains (rice, corn and wheat) and have been realized mainly from new high-yield varieties coupled with adequate supplies of fertilizer, pesticides, water and modern implements. It is expected that the new technology will quickly spread within the nations and across national boundaries. Therefore, provided that increased production is actually obtained by the presently developing countries, a new set of agricultural problems can be anticipated, for which new solutions must be discovered. The purpose of this paper is to place these probable future problmes of agriculture in perspective, to suggest some methods by which solutions may be sought, and to study specifically the importance of planned agricultural diversification as a contributor to these solutions.

Viewing historically Taiwan's experience in the *ponlai* rice revolution of the 1930's, two facts appear which are worthy of attention: the market price of *ponlai* rice is higher than that of the native variety, and intensive cultivation with heavy fertilization and labor input is more profitable with *ponlai* than with native rice. Thus the economic advantages of innovation persuaded Taiwan's farmers to shift from extensive to intensive cultivation.[1]

However, there is reason to believe that such favorable conditions do not yet exist in Southeast Asia. The major goal of most nations which are eagerly promoting seed/fertilizer revolutions is to reach self-sufficiency in food production. The Philippines claims to have achieved some self-sufficiency; Indonesia and Malaysia are expected to be self-sufficient in food production in the early 1970s; rice-exporting contries such as Thailand, Burma and Taiwan will increase their surpluses of rice. The prices of food crops will go down due to these domestic self-sufficiencies and regional surpluses. Domestically, this will create an unfavorable price-cost ratio for farmers who adopt the new technolgy. Regionally, unfavorable terms of trade will worsen the trade positions of the food-exporting countries. These factors will be retarding influences upon the Seed/fertilizer revolution in Southeast Asia.

The current success of the seed/fertilizer revolution is merely the result of national drives to "catch up", to close the technological gap between developed and developing countries. In Southeast Asia, however, there are no strongly organized systems for the spread of technology, no systems for protection against crop disease nor for the breeding and multiplication of new seeds. These lacks inevitably leave farm incomes unstable as farmers assume the risks of innovation. If the influences of price and other technical factors upon farm income are disregarded, population increases will quickly offset the effects of agricultural progress. To bridge the gap between the seed/fertilizer revolution and its economic consequences, agricultural diversification is cited more and more by economists and others concerned as being vitally important to technical and economic considerations relating to agricultural development.

In order to demonstrate the importance of diversification relative to agricultural development in Southeast Asia, this paper will examine:

I. The relationship between farm-income and land productivity in a labor-surplus economy;

II. Technological and economic interpretations of agricultural diversification;

III. Cropping systems with high labor-absorbing capacity;

IV. The conditions necessary for promoting diversification with labor-intensive farming as exemplified by Taiwan.

The paper will conclude with suggestions as to the types of research which should be undertaken in promoting diversification. To sustain the processs of agricultural development in Southeast Asia, technological innovation in labor use must become increasingly effective. In choosing crop patterns and crop-livestock combinations, high labor absorption as well as technical efficiency will be good criteria to follow.

I. The relationship between farm income and land productivity in a labor-surplus economy

To understand clearly the prerequisite conditions for agricultural diversification, it is necessary to understand the objectives of farmers' economic behavior and the bapic principles underlying production factors on Asian peasant farms. From the standpoint of economic theory, labor productivity is the most reliable indicator of economic effifiency. It is believed that when labor is basic to production, the more a unit of labor produces, the more it will contribute toward increasing the netnational product; and that, as a result, per capita income will be increased and the standard of living improved. In other words, to increase labor productivity is to take an important step toward a sound national economy. And, where land and capital are abundant, capital-intensive production is being introduced with a view toward reducing the relative input of labor. However, where labor is in surplus and potential farm land is limited, it is impossible to raise farm-labor productivity through laborsaving.

The conditions basic to the current agricultural prductivity of southeast Asia are the virtural human saturation of all farm lands and the heavy pressures of population upon agriculture. Southeast Asia's prime agricultural problems are population and unemployment. Increased employment opportunities and increased agricultural production can be had by encouraging the types of farming and cropping systems that can absorb large labor inputs and turn out increased production per unit of area. Given such limited land areas as those in Southeast Asia, it is quite logical to assume that increasing land productivity is the only feasible way toward agricultural development. Increasing land productivity would enhance the gross labor return; and gross labor return is directly affected by intensive utilization of farm land and labor as well as by improvements in the cropping system. This relationship is described below.

Chart 1-A relates to the production function of crops under the extensive farming system. The wage rate is represented by the line OP, and the degree of intensity of labor is revealed at point R_1 where lines m.p. and P intersect. Labor input is represented by the line ON_1; of after the use of labor (ON_1) there still remains some surplus labor which cannot find employment, it is anticipated that farmers will be generally unwilling to invest more hours when their gross labor return is already equal to or greater than the disutility of working or of family outlays. But when there is no labor surplus, when the wage rate is high, and a bountiful harvest is in sight, farmers will then be glad to adopt the extensive farming system illustrated in **Chart 1-A.**

However, on small peasant farms the case is different. There is surplus labor, and this lobor needs living expenses not covered by income from farming. Here the farmers desire to put more labor into farming in order to get more return from the land. This is quite commonly true in countries where the owner-farmer sys-

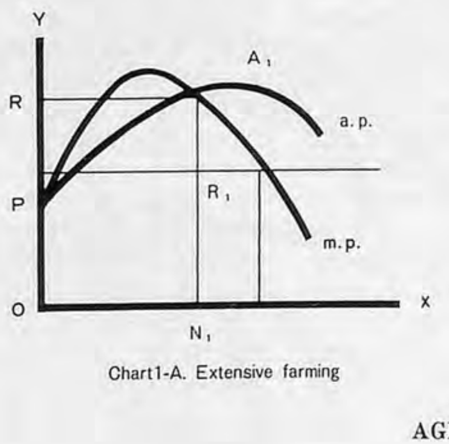


Chart1-A. Extensive farming

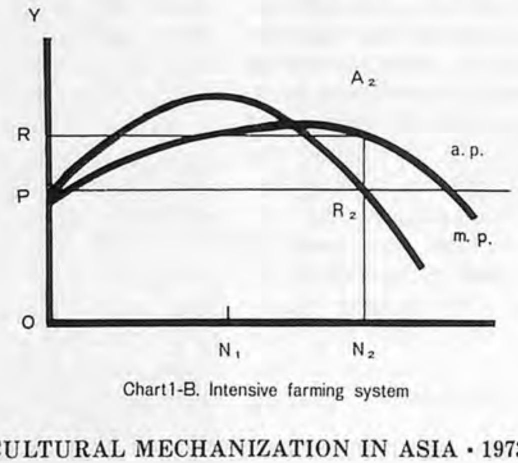


Chart1-B. Intensive farming system

tem predominates and increase in land productivity belongs to the ownerfarmer. These farmers wish to adopt intensive farming so as to incorporate a greater labor force into agricultural production. **Chart 1-B** illustrates the production function of the intensive farming system. In one small farm area a farmer may plant several kinds of crops, and while there are different ways of setting up an intensive diversification system, its labor input is greater than that shown in Chart 1-A (lines N_1N_2), its average labor productivity is less (N_2A_2), and its gross labor return is higher (OR A_2N_2).

II. Technological and economic interpretations of agricultural diversification[2]

When the intent is to increase and stabilize farm income, the method of iso-land analysis offers means to investigate the quantitative reiationship between one product and another in conditions where land is limited. The best cropping system for Southeast Asian agricultural diversification is shown to be a combination of crops and livestock, one which brings the largest returns from allocating limited resources to each cropping system.

Essentially, there are three "basic relationships" in production economics: the factor-product relationship, the factor-factor relaqionship, and the product-product relationship. It is the last relationship which concerns the allocation of fixed resources as between crops and livestock.

Analyzing the third relationship in further detail, we find three kinds of relationships existing between two kinds of crops (or enterprises) when they utilize the same fixed resources, whether at the same or at different times. When resources are fixed, two crops (or enterprises) have (1) a competitive relationship, if the increased production of one crop or enterprise would cause a decrease in the production of the other; (2) a supplementary relationship, if the production of one crop or enterprise could increase whether or not there were changes in production of the other; (3) a complementary relationship, if increased production of one crop or enterprise would cause an increase in the production of the other. Now, if the quantities produced from each of the two crops or enterprises are represented by $y_1$and y_2 respectively, and their changes by Ay_1- and Ay_2, then $Ay_1$and Ay_2represents the marginal rate of substitution. Competitive, supplementary, or complementary relationships correspond respectively to rates less than, equal to or larger than zero.

For example, when two crops such as grain and beans alternate in a cropping system, various types of rotation can apply based on different cropping ratios. When the type which is basically a cropping of grains shifts gradually to the type which includes more beans, the production-opportunity curve often shows a complementary relation at first, and then becomes competitive. Such a curve is called a rotation curve. On the rotation curve in **Chart 2-A**, each point on the curve ab (a,l,m,n,p,q,b) represents a cropping system or a type of rotation. The two crops are complementary between points a and m; at m, they become briefly supplementary; and from m to b they are competitive.

Two conditions are necessary for establishing a supplementary relationship, without competitiveness, between two crops in a cropping system. The first condition is the supply of the limited resource under consideration, suce as land, should be constant and continuous. If the fixed resource is capital services, such as fertilizers and chemicals which vanish after they are applied, the relationship is always competitive, never supplementary.

The second condition is that the two crops differ in their cropping seasons. It is very rate that a supplementary relationship emerges if the two crops have the same cropping season. If one crop can mature fully by utilizing the sunshine, heat and water remaining from the cultivation of the other (as soybeans, for example, can grow between the rows of rice) a supplementary relationship may occur between them but such a case is very rare. For these reasons, it becomes useful to classify crops according to their seasons, as winter, spring, summer and autumn crops.

What is really noteworthy here is that both necessary conditions are related to time. Since it is basic to the formulation of a supplementary relationship that the service of the fixed resource be a constant flow, the use of that resource may be called a supplementary service; at the

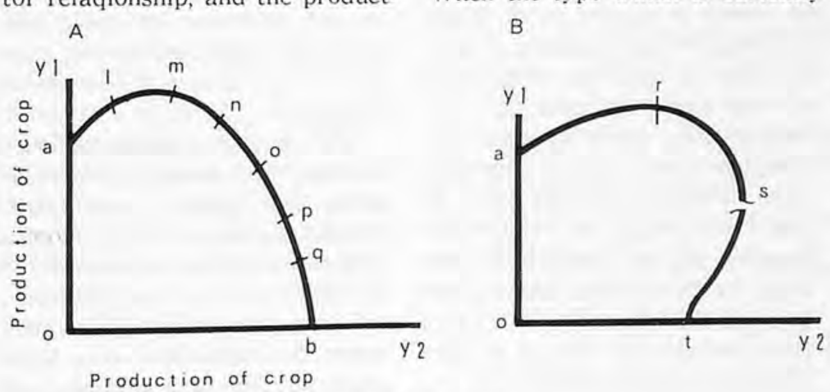


Chart2. Rotation curve

same time, it may also be called a non-interchangeable seuvice, since the use of the resource cannot be diverted into a different cropping season.

We see then that two crops in the same cropping system can become supplementary if for each the services of fixed resouces remain in constant flow and if their cropping seasons are (usually) different. Where such a supplementary relationship occurs, it is possible that a complementary realationship will also emerge, provided that certain other conditions pertain.

A complementary relationship emerged between grains and beans when the production of grains from a given area of land increased after the introduction of beans into a cropping system which had consisted soley of single-crop grains. Suppose a field produces an average 2.0 M/T of brown rice per hectare yearly in single cropping of rice. If soybeans are introduced as a winter crop and rotated with rice, and the yield of rice increases to 2.5 M/T per hectare in addition to the new production of soybeans, a complementary relationship exists.

This is so because soybeans give, in addition to the harvested stems and leaves, some nutritive by-products which imporve the yield of rice. In many cases, soybeans are used as a leguminous crop which provides to rice (or grains) such by-products as these:

- fertilizing elements, especially nitrogen, which are accumulated in the soil by soybeans;
- residues of the roots of soybeans (organic matter) remaining in the soil;
- physiological, chemical and biological improvements to soil conditions which occur with the growing of soybeans.

What should be noted here are the causes of the complementary relationship. Not only do by-products of soybeans remain in the soil and become inputs to rice, but other important effects are the physical, chemical and biological improvements to soil fertility. Also important is the fact that the investment of scarce resources (capital other than land) used in growing the rice crop was kept equal to or less than that needed in growing rice alone. If these conditions were not fulfilled, the iso-land analysis procedure would hardly be appropriate.

In applylng the iso-land method of analysis the production relationships between two crops in double cropping, there will be no problem if the input of capital to crop y_2 is negligible. But if crop y_2 requires a substantial input of capital, the net product of crop y_2(calculated by substracting from the value of gross produce the value of capital used) should be compared to its gross product in order to ascertain which kind of marginal relationship, i.e., competitive, supplementary or complementary, exists between them. Further, it may also be possible to study the relationship between the net products of each crop, by calculating also the net product of crop y_1. In the case of labor redundancy, the net product of each crop should reflect the return to labor, and the labor-absorbing capacity of each crop will be taken into consideration togther with the technological relationship between the crops.

Table 1. Labor Requirements of Basic Crops

	Labor Requirement (Man-days)	Growing period (days)	planting Time	Harvest Time
1st rice crop (Ponlai)	103	125	Late February	Early July
1st rice crop (Native)	99	100	Late February	Early June
2nd rice crop (Ponlai)	100	125	Mid-July	Mid-November
2nd rice crop (Native)	98	125	Late July	Late November
Fall plantings (potato)	78	185	Mid-July	Early January
Winter-crop potatoes	106	110	Mid-November	Mid-February
Wheat	97	120	Early November	Late February
Peanut	107	136	Mid-February	Early July
Rapeseed	80	105	Early November	Early February
Musk Melon	172	25	Early June	Late July
Cabbage	256	98	Late October	Early February
Leaf Mustard	207	103	Early November	Early February
Chinese Cabbage	354	95	Early November	Mid-February
Tobacco	800	110	Mid-November	Late February
Fall-crop sugarcane	145	480	Early September	Mid-December

III. Cropping systems with high labor-absorbing capacity

The intensive farming system is, as has been stated above, only an explication of theory. There are, however, varying forms of cropping systems as adopted by the farmers, corresponding to the natural conditions, marketing systems and supplies of farm labor. Generally speaking, these are the multiple cropping system, the rotational cropping system, the crop-and-livestock integrated farming system, and the crop-and farm-product-processing integrated system. This discussion will concern only the relation between intensity of labor use and the several intensive cropping systems. The labor inputs for crops grown in Taiwan follow below (**Table 1**).

The shortest growing period is 45 days, the average period is 185 days, the longest period (fall-planted sugarcane) is 16 months. The lowest labor requirement is 78 man-days and the highest is 800 days. There are wide differences in capacities for labor-absorption in these varying growing periods. Generally the grain

Table 2. Cultivated Area, Cropping Area, Labor Force

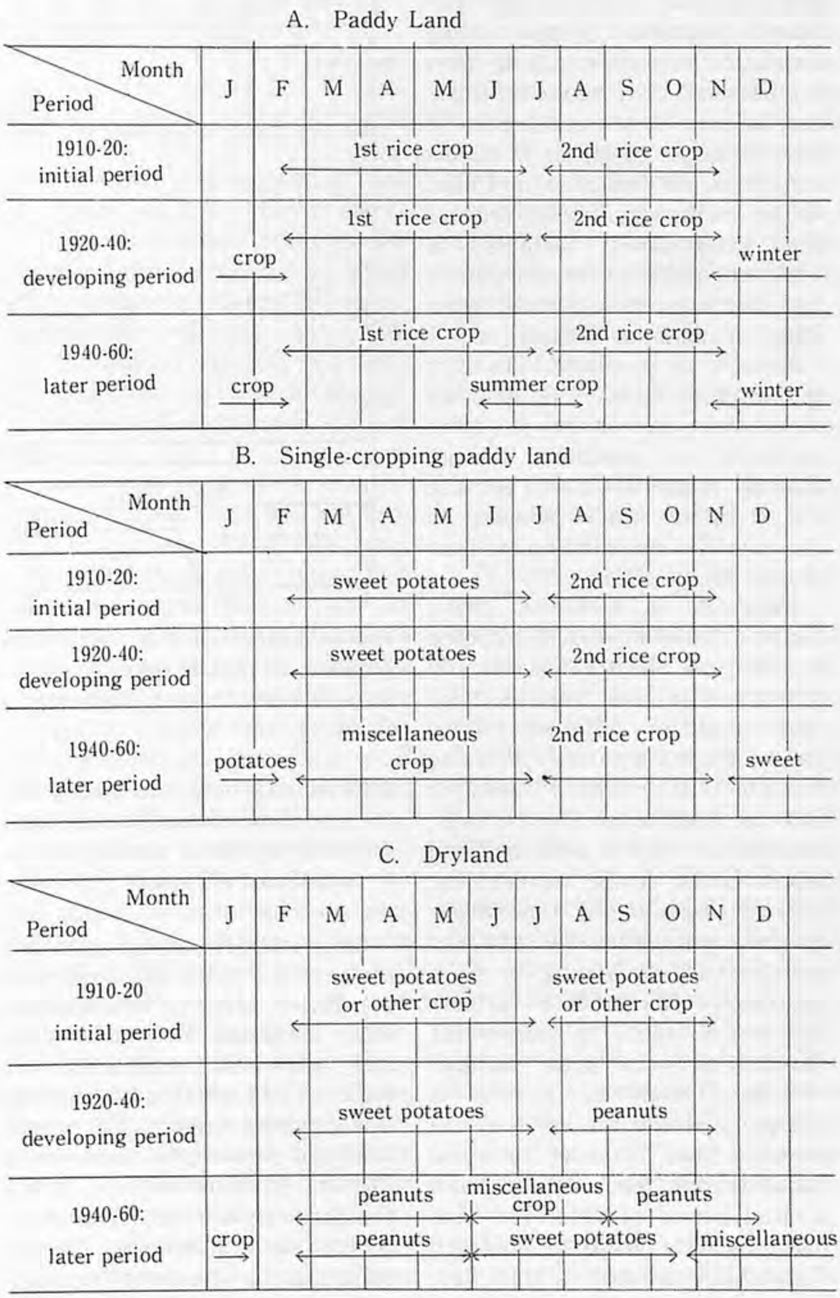
Period	Cultiv. area (ha)	Crop area (ha)	Labor (1,000 Persons)	Ag. Pop. (1,000 Persons)	Cultiv. Area/Ag. Pop. (ha)	Cultiv. area per Laborer (ha)	Crop area per Laborer (ha)	Multi-crop index %
1911-1915	692,272	806,282	1,155	2,199	0.31	0.60	0.70	116
1916-1920	731,288	865,561	1,124	2,288	0.32	0.65	0.77	118
1921-1925	758,538	920,177	1,126	2,271	0.33	0.67	0.82	121
1926-1930	802,222	982,261	1,188	2,452	0.33	0.68	0.83	122
1931-1935	820,304	1,079,004	1,286	2,658	0.31	0.64	0.84	132
1936-1940	856,108	1,138,520	1,374	2,908	0.29	0.62	0.83	133
1941-1945	837,015	1,098,007	—	3,242	0.26	—	—	131
1946-1950	852,911	1,288,308	1,658	3,752	0.23	0.51	0.78	151
1951.1955	873,962	1,501,891	1,741	4,378	0.20	0.50	0.86	172
1956-1960	875,897	1,575,849	1,725	4,944	0.18	0.50	0.91	180

Source: T.H.Lee, "*Intersectoral Capital Flows in the Economic Development of Taiwan, 1895-1960*", Ph.D.Thesis, Cornell University, 1968; Chapt. 4.

crops require fewer labor-days; vegetables and horticutural crops require more. Different varieties of the same basic crop, such as *Ponlai* and native rice differ in their requirements for labor.

These basic crops, which differ in growing periods, and require differing numbers of labor-days, can be integrated into a cropping system designed to absorb the highest practicable labor input. Fertility of the soil, capacity for labor input, and gross labor return are the determining factors in setting up a cropping system. In Taiwan, farmers usually combine two or three kinds of cropping. The increased number of labor-intensive cropping systems is reflected in the rise in the multiple-cropping indexes which are shown in **Table 2.**

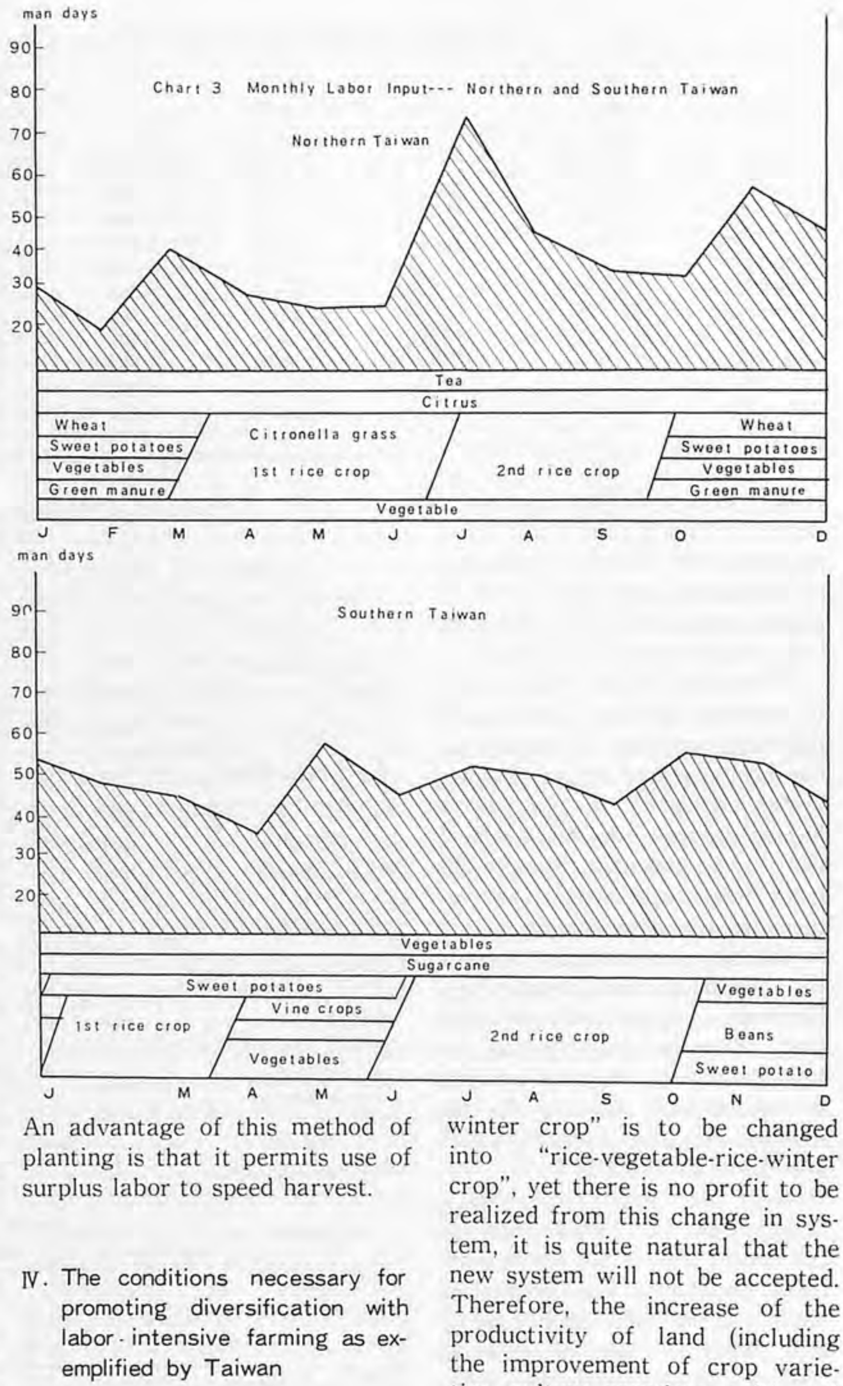
Over the past fifty years, arable land in Taiwan has increased by 26% while the agricultural population has grown by 125% and the farm labor force by 50%. With the rapid increases of agricultural population, there has been a decline in the farm labor force in proportion to the total agricultural population and a decrease in size of cultivated areas. Prior to 1935, increases in cultivated land were possible due to the fast expansion of newly-reclaimed lands. After 1940, however, population pressure grew rapidly and the only way to meet the changing need is to make intensive use of land and multiply the croppings. The multiple-crop-



ping index indicates that the number of crop plantings steadily increased after 1935 with the result that there has been also a gradual increase in the cropping area per farm laborer. These changes are reviewed in the following tables.

The labor input per hectare of cultivated land has increased from 195 man-days in 1911-1915 to 220 days in 1931-1935, and further increased to 305 days in 1956-1960. The seasonal distribution of labor is more equitable following the introduction of the labor intensive system. The impact of intensive-cropping upon the seasonal distribution of labor can be seen in a cross-section of the intensities of larbor in different areas. As indicated in **Chart** 3, the average cultivated area of the investigated farmers in northern and southen Taiwan is 1.45 hectares; the annual labor input in northern Taiwan is 577 man-days, in southern Taiwan it is 658 man days. The monthly distribution of labor is more equitable in southern Taiwan than in northern Taiwan because the cropping system adopted in the south is more complex than that of the north.

Farmers in Taiwan have adopted labor-intensive cropping in order to absorb more family labor, and so plant various crops that require different labor inputs. Such a system will waste no labor, but instead tends to increase simultaneously the average productivity of both land and labor. Under it the demand for labor is high as the time available for harvesting one crop and planting the following crop is extremely short. Some farmers use power tillers to supplement human labor in peak demand periods. Sometimes, a crop is planted between the rows of the previous crop in order to avoid concentrating labor demand into a short period of time. The vine and vegetable crops of southern Taiwan are planted in this way.



An advantage of this method of planting is that it permits use of surplus labor to speed harvest.

IV. The conditions necessary for promoting diversification with labor-intensive farming as exemplified by Taiwan

Iabor-intensive cropping is one of the useful methods of relieving population pressure and seasonal labor surpluses. Favorable social and economic conditions are required to facilitate adoption of this cropping system. First of all, it should provide the increases in farmers' income without which the farmers will be reluctant to accept such a system. For instance, if the system of "rice-rice-winter crop" is to be changed into "rice-vegetable-rice-winter crop", yet there is no profit to be realized from this change in system, it is quite natural that the new system will not be accepted. Therefore, the increase of the productivity of land (including the improvement of crop varieties, culture practices, cultivated land and the increase of the demand for farm products) is prerequisite to the success of this system. The following is a statement of the improvement of crop varieties, culture practices and cultivated lands in connection with the adoption of labor-intensive cropping in Taiwan.

(a) Improving crop varieties and culture practices

Table 3. Cultivated land, Irrigation, Multiple-cropping Index*

Locality	Cultivated area (ha)	Irrigated area (ha)	Ratio: irrigated area / cultivated area	Multiple cropping index %
Taipei	50,950	21,497	42.19	165
Ilan	27,949	23,122	82.73	190
Taoyuan	54,842	32,998	60.17	193
Hsinchu	42,440	10,616	25.01	165
Miaoli	41,415	16,076	38.82	187
Taichung	46,331	38,781	83.70	232
Changhua	76,070	59,908	78.75	233
Nantou	46,228	19,190	41.51	143
Yunlin	86,441	20,730	23,98	195
Chiayi	71.685	149,333	34.31	159
Tainan	96,948			
Kaohsiung	53,803	24,001	44.61	187
PIngtung	77,820	41,154	52.88	196
Taitung	30,612	8,572	28.00	147
Hualien	31,818	10,673	33.54	167
Penghu	7,283	—	—	132
Average	—	—	41.96	184

* From the Agricultural Yearbook 1960 and 1961, published by the Taiwan Provincial Department of Agriculture and Forestry.

There is a shortage of vegetables in Taiwan in summer. If vegetables can be planted in May and June without adversely affecting the second rice crop, income will be increased. There are technical difficulties but following upon improvements in adopting the crop varieties, and practice of interplanting vegetables with other crops, farms in central and southern Taiwan have changed from three crops to four crops per year.

(b) Improving cultivated lands

Improvements to cultivated land includes irrigation, drainage, soil enrichment and other investments. The purposes are twofold: in time of drought or inadequate water supply, irrigated land can support one or even two crops; and after having made such improvements, fertilizer and labor inputs are considerably increased, the farming is more intensive and is then capable of absorbing still more inputs.

Using **Table 3** we can visualize the positive correlation between the amounts of irrigated land and the multiple-cropping index.

(c) Altering the demand for farm products

Demand here includes human consumption plus expanded uses by industrial and other consumers. Rice and sweet potatoes are laborextensive crops. If we wish to substitute plantings of vegetables, citrus, tobacco, and rapeseed for grain crops, for example, we must first find out the market for the intensive crops. If market demand is low, increasing production will tend to lower the prices of these crops and the profits from them would also drop. Vegetables are daily necessities in Taiwan, and therefore the increase of population as well as the large demand for summer vegetables in particular have helped to stablize farm profits by encouraging the introduction of inter-plantings. Winter-planted crops such as tobacco are profitable because the Taiwan Tabacco and Wine Monopoly Bureau purchases tobacco leaf under contracts which offer attractive prices to the sellers. It is logical that farmers should be more inclined toward accepting labor-intensive cropping when those crops reap high profits. Thus, aside from improvements to culture practices and cultivated land, it seems necessary that labor-intensive cropping systems should be further supported by the development of agricultural processing industries and by increases in consumption.

(d) Labor-intensive cropping and the linear programming approach in Taiwan

Itwas asserted earlier that adoption of labor-intensive cropping in an over-populated area having seasonal labor surpluses will help to reduce unemployment and will increase farm income. In order to introduce the system effectively, a cropping system should be devised for a given area, to serve as a guide for individual farm planning. The linear programming approach serves this purpose. If the scales and patterns of operation of farms vary widely in the given area, it may be appropriate to devise several model systems for consideration by the farmers. The model system can be divided into component types of cropping according to these criteria:

a. climate, soil had topography
b. size of cultivated area, labor force and animal stocks
c. availability of farm implements and other equipment

Of these criteria, one or two may be chosen as the basis for establishing a particular cropping system. When the several areas are similar to each other, in natural and equivalent farm conditions, for example, the choice as to the type of farming can be based upon the size of the cultivated area, the labor farce and the animal stocks. The objectives include achieving the maximum income derivable from the family's labor and from their land. Attaining these objectives means making full use of the available crop area and labor force. Following is an account of several of the most profitable systems adopted by Lung Tung Village of Lung Chin Township in central Taiwan.

This township carried out a large-scale-land-consolidation pro-

Farm Families, livestock and poultry, Lung Tung Village

	No. of families	No.of family members	Farm labor force	Livestock Cattle	Hogs	Chickens	Cultivated land (ha)	Paddy land (ha)	Dry land (ha)
Totals	198	1,643	614	163	240	1,230	81.33	77.17	4.16
Average family		8.3	3.1	0.8	1.2	6.2	0.44	0.39	0.05

The above table shows that in Lung Tung Village the man-land ratio is very high.

Acreage allocations: Existing conditions of crop production Lung Tung Village

	Planted area (ha)	Average area per family (ha)	Distribution of planted areas (%)
Total	202,40	1,023	100
1st rice crop	76.38	0.39	38.12
2nd rice crop	76.13	0.38	37.15
Wheat	32.05	0.16	15.64
Sweet potato	3.72	0.019	1.86
Beans	0.24	0.001	0.10
Rapeseed	6.91	0.035	3.42
Flax	0.44	0.002	0.20
Muskmelon	2.99	0.015	1.47
Vegetables	2.16	0.011	1.07
Other	1.38	0.01	0.97

ject. It has fertile soil, adequate irrigation and drainage facilities. With the exception of monsoon winds, the climate is favorable for various kinds of crops. The land is on the plain and with Taiwan Strait to the west and Taichung city to the east, it became a center of food production and consumption. Its agricultural products are accessible to northern and southern Taiwan through railway and highway transport.

The informational base for planning was derived from surveys of farm economy and production costs of the staple crop in Lung Chin Township, conducted by the Taiwan Provincial Department of Agriculture and Forestry in 1961 when land consolidation had been carried out.

The rate of land utilization or index of multiple cropping is 249%. Rice occupies the largest portion of the total planted acreage, and we can see that Lung Tung Village is much like other areas which emphasize the cultivation of rice.

The first step in planning is determination of the average size of cultivated areas and of the labor froce; from this planners proceed to considerations of the five types of systems and make trial computations in each system. (In the following table, 0.5 hectare and 3 workers represent the "average" farm.)

Cultivated area (ha)	Labor force I	II	III
0.3	2.5	3	3.5
0.5		3	3.5
0.7			3.5

The important crops that can be planted in this village during the frist crop season (March-June) are rice, vegetables, watermelons, peanuts, tomatoes, cucumbers; during the summer season (June-August), muskmelons, watermelons, vegetables; during the second crop season (August-November), rice, sweet potatoes, vegetables; during the winter season (November-March), wheat, vegetables, rapeseed, peas, flax, etc. The raising of livestock and poultry is so restricted by the shortage of feed crops that the average number of hogs per family is 1.2; of chickens 6.2; of cattle 0.8. In spite of the underdevelopment of livestock and poultry in this village, some land is devoted to sweet potato intended for animal feed. The raising of livestock and poultry will not be considered in this program plan, however.

The labor coefficient of crop planting represents the number of days required for planting that crop on one hectare of land and was calculated on the basis of survey figures from one village and verified in the survey of the township. Farm price represents the average over a three-year period.

The information presented above may be summarized as follows:

a. Resource limitations

The standard cropping area is 0.5 hectare, of which 0.45 hectare is paddy land and 0.05 hectare is dryland. The average family owns one hog, for which 0.03 hectare of dryland is needed for raising 400 kilograms of sweet potatoes annually. Cropping is then confined to 0.45 hectare of paddy land in the first, summer, second and winter seasons, and 0.02 hectare of dry land in the first, second and winter seasons.

The Taiwan Food Bureau extends loans to farmers for purchases of fertilizers. No special or additional farm implements or other capital goods are needed in the labor-intensive cropping system.

b. Labor limitations

Working 25 days each month, the three wrkers in an average family contribute 75 man-days. Five days are spent on hog raising and sweet potato planting, leaving a net labor supply of 70 days.

No restriction is assumed with respect to the rate of land utilization for various crops. All factors relating to pest and disease damage and to economic risk dispersion are omitted from consideration in this program.

The simplex table:

Based on revenue coefficients, techinical coefficients and resource limitations, a simplex table of the first stage is prepared as follows (0.5 hectare and 3 workers represent a "typical" unit for computation purposes).

Table 5 supplies the basic information required for the simplex table. The simplex table reveals the input and output coefficients derived from the basic information and the resource limitations shown in **Table 4.** The results of computations of the first and last (seventh iteration) stages of the simplex table are shown in **Tables 6** and **7.** Since the iteration of computation in linear programming is a purely mechanical process, the intermediate stages are omitted. The intensive use of paddy land and dryland as outlined in **Table 7** may be summarized on the downward table.

Farmers spend 330 days planting the above crops on an area of 0.47 hectare, or 702 days on one hectare. Also the 60 days required for annual feed production and livestock raising should be added. This represents a yearly increase of 83 days as compared to the average labor of 307 days per family in the extensive system. Farm income has risen from NT$11,825(before programming) to NT$25,941(after programming), an increase of NT$14,116. The man-land ratio in Lung Tung Village seems very high inasmuch as the labor force is 3 persons and cultivated land is 0.5 hectare per family. Hence there is no effective way for the labor-intensive system to make full use of the labor force. The shadow price of labor, as indicated in **Table 7**, is zero.

Table 4. Resource limitation under the base program

Cultivated area (ha)	0.3		(typical situation) 0.5		0.7
Labor force (workers)	2.5	3	3	3.5	3.5
Ist crop paddy land (ha)	0.3	0.3	0.45	0.45	0.65
Summer crop paddy land (ha)	0.3	0.3	0.45	0.45	0.65
2nd crop paddy land (ha)	0.3	0.3	0.45	0.45	0.65
Winter crop paddy land (ha)	0.3	0.3	0.45	0.45	0.65
Ist crop dryland	—	—	0.02	0.02	0.05
2nd crop dryland	—	—	0.02	0.02	0.05
Winter crop dryland	—	—	0.02	0.02	0.05
Labor (man-days)					
January	62.5	62.5	70	82.5	80*
February	62.5	62.5	70	82.5	80
March	62.5	62.5	70	82.5	80
April	62.5	62.5	70	82.5	80
May	62.5	62.5	70	82.5	80
June	62.5	62.5	70	82.5	80
July	62.5	62.5	70	82.5	80
August	62.5	62.5	70	82.5	80
September	62.5	62.5	70	82.5	80
October	62.5	62.5	70	82.5	80
November	62.5	62.5	70	82.5	80
December	62.5	62.5	70	82.5	80

*Some labor has been allotted for a larger dryland acreage of sweet potatoes(0.045 ha.) and only 80 labor days remain available.

Cropping system

Month	J F M A M J J A S O N D
Paddy land	First crop paddy rice (0.45 ha) ←→ ; Second crop paddy rice (0.45 ha) ←→
	winter cabbage → (0.45 ha) ; Muskmelon (0.45 ha) ←→ ; Winter cabbage ←
Dry land	Peanuts (0.02 ha) ←→ ; Fall-planted sweet potato ←→ (0.02 ha)
	winter cabbage ←→ (0.02 ha) ; winter cabbage ←

Aside from the changes made in the cropping system, other farm sidelines such as livestock and poultry, should also be encouraged in order to make the fullest use of the family's labor.

The cropping system computed by linear programming can be developed into easily-adopted types if varlons are changed. These will serve as bases for improving farm management.

Conclusions and Research Suggestions

Drawing upon theoretical and historical backgrounds, we have examined in detail the impact of farm labor surpluses on cropping systems and we have reviewed the system of intensive farming. The linear programming approach has been used to compute, using concrete examples, a labor-intensive cropping system which can become the basis for improving farm management. Results show that such a system produces great effects upon the use of labor coupled with limited land resources, upon farm income, and upon farm labor unemployment. It does not, however, solve the problem of labor surplus if the surplus is excessively large. Given limitations in variety of crops plus seasonal variations in demands for labor, the key to solving the labor surplus lies in improving culture practices and expanding domestic consumption. When arable land is extremely scarce, the important pre-conditions are to make intensive use of land, as a land-saving device, and to widen the variety of crops as was done in Taiwan.

In order to form crop complexes or to diversify farming more efficiently, these research

Table 5. Basic Information

Items \ Crops		1st paddy	2nd paddy	Fall sweet potato	Winter sweet potato	Leaf mustard	Wheat	Rape green	Musk-melon	Cabbage	Chinese cabbage	Cauli-flower	Pea-nuts
Yield	kg.	4,396	3,334	14,111	17,042	31,200	1,978	1,602	15,181	52,841	25,688	12,453	1,001
Unit price	NTS	3.90	3.78	0.62	0.56	0.52	3.55	6.64	1.07	0.53	0.96	1.09	6.00
Total return	NTS	17,158	12,597	8,811	9,626	16,329	7,108	10,434	16,313	28,261	24,693	13,673	6,006
Ferti-lizer	NTS	2,094	1,723	1,232	1,884	4,151	2,396	2,091	3,374	4,333	3,688	2,185	537
Pesti-cides	NTS	441	296	56	13	443	143	150	1,747	677	8 83	304	9
Seed & Seedling	NTS	214	227	491	536	829	462	67	118	1,468	1,306	736	743
Deprecia-tion	NTS	463	293	196	196	270	243	243	352	320	228	227	210
Total cost	NTS	3,212	2,539	1,975	2,629	5,693	3,244	2,551	5 591	6,798	6,105	3,452	1,499
Net income	NTS	13,946	10,058	6,836	6,997	10,636	3,864	7,883	10,722	21,463	18,588	10,221	4,507
Labor (man-days)	Jan.				15	25		7		26	38	68	
	Feb.	33			25	69	44	35		85	111		13
	Mar.	49											16
	April	26											18
	May	32											10
	June	3							87				49
	July		44	29					87				
	Aug.		29	19									
	Sept.		21	4									
	Oct.		13		40								
	Nov.		33	6	26	77	40	31		93	143	79	
	Dec.			19		39	30	24		52	57	23	

programs are recmmended:

(a) To understand the different requirements and possibilities of various products and the technological characteristics of land use for various crops, a farm economy survey and research should be made on: climate, soil requirements, input-output relationships between grain and non-grain crops and livestock.

(b) Long-term projections of national food consumption, which are necessary to an understanding of future patterns of crop and livestock requirements, will throw light on the economic considerations related to choosing an efficient cropping system.

(c) Famers' responses to price changes in crops other than grain should be surveyed. This will bring out a clearer picture of feasible resource allocations.

(d) Some search of domestic and regional crops and live-stok should be underqaken in terms of their comparative economic advantages.

(e) Farmers' organizations for the extension of new technology, for breeding new varieties, and for protection against natural risks will be important in promoting agricultual diversification. Sociological analyses of the impact of farmers' organizations will be useful. ■ ■

1) T. H. Lee, *Intersectoral Capital Flows in the Economic Development of Taiwan,* 1895-1960, Chapter 4, p. 64 (forthcoming publication of Cornell University Press).

2) For information given in this section the author has drawn extensively from Tohei Sawamura's articles on paddy cropping patterns in Japan.

(This paper was presented at a SEADAG Rural Development Panel Seminar held in Manila, Philippines on January 6-8, 1971)

Table 6. The First Stage of Simplex Table (Cultivated land 0.47 ha. and labor force 3 persons)

Table 6. The First Stage of Simplex Table (Cultivated land 0.47 ha. and labor force 3 persons)

C		13,946	10,058	6,836	6,997	10,636	3,864	7,883	10,722	21,463	18,588	10,221	4,507																				
Basis	P_0	1st paddy P_1	2nd paddy P_2	fall sweet potato P_3	winter sweet potato P_4	leaf-mustard P_5	wheat P_6	rape greens P_7	musk-melon P_8	cabbage P_9	chinese cabbage P_{10}	cauli-flower P_{11}	Peanut P_{12}	1st paddy field P_{13}	inter cropping field P_{14}	2nd paddy field P_{15}	Winter cropping field P_{16}	1st upland P_{17}	2nd upland P_{18}	Winter Cropping upland P_{19}	Labor Jan. P_{20}	Feb. P_{21}	March P_{22}	April P_{23}	May P_{24}	June P_{25}	July P_{26}	Aug. P_{27}	Sept. P_{28}	Oct. P_{29}	Nov. P_{30}	Dec. P_{31}	R
P_{13}	0.45	1												1																				∞
P_{14}	0.45								1						1																		∞
P_{15}	0.45		1													1																	∞
P_{16}	0.45				1	1	1	1		1	1	1					1																0.45
P_{17}	0.02												1					1															∞
P_{18}	0.02			1															1														∞
P_{19}	0.45				1	1	1	1		1										1													0.02
P_{20}	70				15	25		7		26	38	68									1												2.69
P_{21}	70	33			25	69	44	35		85	111		13									1											0.82
P_{22}	70	49											16										1										∞
P_{23}	70	26											18											1									∞
P_{24}	70	32											10												1								∞
P_{25}	70	3							87				49													1							∞
P_{26}	70		44	29					87																		1						∞
P_{27}	70		29	19																								1					∞
P_{28}	70		21	4																									1				∞
P_{29}	70		13		40																									1			∞
P_{30}	70		33	6	26	77	40	31		93	143	79																			1		0.75
P_{31}	70			19		39	30	24		52	57	23																					1	1.35
Z	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Z-C	0	-13,946	-10,058	-6,836	-6,997	-10,636	-3,864	-7,883	-10,722	-21,463	-18,588	-10,221	-4,507	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table 7. The Last Stage of Simplex Table (Seven interation) (Cultivated land 0.47 ha. and labor force 3 persons)

C																																	
Basis	P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	P_{20}	P_{21}	P_{22}	P_{23}	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}	P_{29}	P_{30}	P_{31}	R
P_1	0.45	1												1																			
P_8	0.45								1						1																		
P_2	0.45		1													1																	
P_7	0.45				1	1	1	1		1	1	1					1																
P_{12}	0.02												1					1															
P_3	0.02			1															1														
P_7	0.02				1	1	1	1		1										1													
P_{20}	57.78				-11	-1	-26	-19		0	12	42					-26			-26	1												
P_{21}	14.94	0			-60	-16	-41	-50		0	26	-85	0	-33			-85	-13		-85		1											
P_{22}	47.63	0											0	-49				-16					1										
P_{23}	57.94	0											0	-26				-18						1									
P_{24}	55.40	0											0	-32				-10							1								
P_{25}	28.52	0							0				0	-3	-87			-49								1							
P_{26}	10.47		0	0					0						-87	-44			-29								1						
P_{27}	56.57		0	0											-29			-19									1					
P_{28}	60.47		0	0											-21			-4										1				
P_{29}	64.15		0		40										-13													1			
P_{30}	11.32		0	0	-67	-16	-53	-62		0	50	-14				-33	-93		-6	-93											1		
P_{31}	45.18			0	-52	-13	-22	-28		0	5	-29					-52		-19	-52												1	
Z	25,941.17	13,946	10,058	6,836	21,463	21,463	21,463	21,463	10,722	21,463	21,463	21,463	4,507	13,946	10,722	10,058	21,463	4,507	6,836	21,463	0	0	0	0	0	0	0	0	0	0	0	0	
Z − C	25,941.17	0	0	0	14,466	10,837	17,599	13,580	0	0	2,875	11,242	0	13,946	10,722	10,058	21,463	4,507	6,836	21,463	0	0	0	0	0	0	0	0	0	0	0	0	

NEWS

FOOD AID AND POPULATION CONTROL

WFP Policy on Family Planning

(*World Food Programme News*, July-October 1972)

"There will be twice as many people on our planet in the year 2000, twice as many mouths to feed." At the recent Stockholm United Nations Conference on the Human Environment, the Director-General of FAO, Dr. Addeke Boerma, spoke of "the appalling increase in population" and how attempts to feed these multitudes will affect the human environment.

"Most of this increase will occur in the developing, already undernourished and overpopulated parts of the world.

"To meet *their* requirements, agricultural production should double every 18 years—a rate never achieved over a sustained period by the countries that are now well fed."

The World Food Programme has recognized that it should do all it can to help governments to implement family planning ever since, a few short years ago, the population explosion began to be officially acknowledged as a clear threat to the success of efforts to help developing countries. For, while family planning still has controversial aspects, it can no longer be denied that with the world population increasing at the rate of 1000 million in about a decade (whereas it took millenia for the first 1000 million to be reached in 1830 and a century for the second 1000 million to be reached in 1930), a continuation of such a rate of increase would soon exhaust the world's immediate food supply and wreak havoc with attempts to increase employment, provide better social and health conditions, and achieve most if not all other development goals. For it also became evident that two thirds of the burgeoning population increase was taking place in the developing countries which are in most cases least able to cope with it without suffering very serious consequences.

United Nations initiative

Hence, when the United Nations took the initiative in 1967 of establishing the Population Fund (UNFPA), and the International Planned Parenthood Federation (IPPF) also came to be consulted more actively by the United Nations family, WFP welcomed these steps and began searching for ways in which it could effectively and usefully collaborate.

In the Programme's view, two main objectives have become imperative in principle, not only for WFP but for all who wish to help the developing world effectively: (a) to continue to improve living conditions, especially for children and mothers; and (b) to slow the rate of population increase in countries which cannot meet the problems caused by current rates of growth.

The second of these two objectives is, of course, not the primary function of WFP—UNFPA has come into being to deal primarily with this. However, WFP should seek every feasible way to collaborate with UNFPA and IPPF. Consequently, with the agreement and counsel of the Intergovernmental Committee, WFP has adopted a basic formula by which to offer such help. As Executive Director Aquino has already made known to UNFPA, WFP will provide available food aid resources to help with family planning if (a) governments so request; (b) practical means can be found for applying food aid to this end; (c) family planning is a supplementary aim and not the principal aim of the project proposed to WFP.

Educating and motivating parents

While few family planning projects have so far been proposed to WFP, it appears likely that WFP will be able to help family planning most in connexion with supplementary feeding programmes, especially through mother and child health (MCH) clinics. Indeed, the major problems in establishing successful family planning programmes are those of educating and motivating parents. MCH clinics provide a very favourable opportunity for putting before mothers particularly the facts and possibilities of family planning.

From the point of view of education, parents need to know what family planning is, and what facilities are available —such as the pill, the condom, the loop and in some cases sterilization. These facilities differ somewhat from country to country, but WFP will only support those that are morally acceptable and meet the terms of the resolution adopted by the United Nations Tehran Conference on Human Rights that "couples have a basic human right to decide fully and responsibly the number and spacing of children, and a right to adequate education and information in this respect." In other words, WFP will only support familly planning which is accepted by parents on a voluntary basis.

It is also completely intolerable to WFP that any conditions be placed on the availability of food aid in order to achieve family planning objectives.

Motivation in terms of family planning is even more important than education. No family planning programme can be successful unless those who are to participate are convinced of its value to them personally. Without such motivation, mothers will soon forget to take the pill, or men to take a responsible attitude. Persons sterilized will regret in and demand to be recapacitated. Unfavourable reactions will occur that will undo hard won results.

Strong economic element

Motivation is apt to need a strong economic element to be enduring. Thus, it is important that parents come to see and to be convinced that it is no longer necessary for them to have many children so that some will survive to assure the parents' economic security in their old age. They should rather come to see that if they have fewer children they will be better able to provide the means through education for their children to attain a higher living standard, and thus, given the child's better chance of survival and old age pensions instituted or being instituted in more and more countries, the parents' own interest will best be served. (Such motivation can, however, only be imparted to parents if the conditions mentioned in fact exist in the societies and countries concerned. This shows how family planning schemes must form a part of a country's development package —another factor to be considered by WFP in evaluating a government's project request or proposal involving family planning.)

Egypt, India, Indonesia, the Republic of Korea and Pakistan are among the countries now engaged in very important family planning activities and programmes. In some of them assistance is being provided by WFP in terms of food aid to MCH clinics through which family planning advice and facilities are being made available, always of course with the government's full knowledge and consent and with the cooperation of UNFPA and usually other appropriate United Nations organizations such as the World Health Organization. WFP is actively seeking ways of making such activities more effective and extending them to other countries and other projects.

Potentialities for WFP cooperation also exist in connexion with other types of project where considerable numbers of people are brought together, such as in labour-intensive projects or community development projects which bring together large numbers of men and women. WFP will welcome family planning related project proposals in connexion with such activities. WFP also looks forward to participation in interagency and international consultations and undertakings, such as the World Population Year programme planned for 1974, as a means of developing new ideas and new possibilities for WFP collaboration in this field.

For clearly much has to be done and done quickly if the population explosion is to be brought under control in good time.

...twice as many people on this planet by the year 2000.

NEWS

Farm Size, Economic Efficiency, and Social Justice

(A case of *Punjab*)


Small mechanical seeders being pulled by 6 hp hand tractor

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Ludhiana, India

At this stage of economic growth and development in India, an over-riding national objective has to be the enhancement of agricultural production, mobilization of agricultural surpluses (marketed surpluses) encouragement of the intersectoral capital flow from agricultural to non-agricultural sector, in order to create more of non-farm gainful employment opportunities. Farm size, productivity, flow of agricultural surpluses, employment within agriculture and the capacity of the agricultural sector to stimulate employment creation in the non-farm sector are intimately linked up. The ceilings on land holdings up to 30 standard acres in Punjab seems to put an appropriate limit on farm size from the point of view of economic efficiency, social justice and employment of farm labour. A set of policies, economic and social, to encourage land holdings around this size seems to be in order with a view to maximize production and marketed surplus per unit of land. Exemptions to hold land above these ceilings do not meet the criteria of economic efficiency and social justice. Lowering of the level of ceilings at the existing level of Production technology, does not seem to meet the test of economic efficiency and is not very certain to expand over all employment because the level of additional employment (or prevented unemployment) can get off-set by reduction in production, marketed surplus and capital out-flow, correspondingly reducing the level of employment in the non-farm sector.

The development of an agrarian economy depends directly on the growth of its agricultural sector. Efficiency or inefficiency of this leading sector gets reflected into the pace of growth of the total economy. The level of efficiency in the agricultural sector not only affects the total agricultural production, more so it influences what flows out of this sector to the non-farm sector (agricultural surpluses). From the point of view of growth and development of an economy an increase in the agricultural production loses much of its significance unless it is followed by an increase in the marketed surplus, because it plays a vital role via the interesectoral capital flow and the cheapening of wage goods[1]).

Within the farm sector it is of importance as to wherefrom (on what category of holdings) this marketed surplus originates. An analysis of the impact of the size distribution of operational holdings on production and marketed surplus and the income accrual patterns it originates through changes in employment is of prime concern at this stage of development in India. It is especially so when emphasis is being placed on equitable sharing of the fruits of growth due to the green revolution in the farming sector. Such an analysis holds special importance, particularly when land reforms involving downward revisions in ceilings on land holdings are being debated in the country. This paper attempts to examine the questions (i) whether the farm size distribution makes any difference and, if so, in what direction and degree with respect to yield and marketed surplus per unit of land, (ii) how far economic efficiency moves in complementary fashion with social justice, (iii) is there any relationship of employment with farm size distribution, and (iv) whether the step to lower the level of ceilings on farm size can be justified on grounds of economic efficiency and social justice.[2])

Farm Size and Marketed Surplus

In general, the total marketed surplus increases with the increase in the size of operational holdings. From the point of view of the economy as a whole, however, what matters most is the marketed surplus per unit of land (or acre) or as a proportion of the total production. Quite a few studies have been made in India on the marketed surplus as a proportion to the total production for various farm sizes. Investigations in the Punjab State have shown that the marketed surplus bears a direct relationship to the size of holdings in case of foodgrains (1,2,3,6,7)[3]). In case of cash crops, however, the marketed surplus has shown an inverse relationship (3,8). Studies conducted in Uttar Pradesh have also confirmed these findings (11).

The proportion of marketed surplus to the total production in case of progressive farmers in the Punjab worked out to be 54 per cent for small farmers below ten acres, 76 per cent for medium farmers between ten to thirty acres and 84 per cent for large farmers above 30 acres (2). According to a study conducted in Ludhiana district, the consumption of wheat and maize was 90.8 per cent and 72.9 per cent of the total production in case of farms below 5 acres with a corresponding marketed surplus of 9.2 and 27.1 per cent respectively. The consumption decreased to 26.3 and 34.3 per cent with marketed surplus of 73.7 and 65.7 per cent respectively in case of farms 40 acres and above. In the case of farms of five acres and below, 65 per cent holdings had no marketed surplus (2). Gupta in his latest study (1971) showed that marketable surplus of wheat on small farms below 14 acres was 69.76 per cent compared to 76.31 per cent on 14-28 acre farms and 84.48 per cent on farms above 28 acres. Similarly, for maize the marketable surplus was 59.19, 66.48 and 69.82 per cent on small, medium and large holdings respectively. For groundnut the corresponding figures were 69.72, 80.54 and 83.93 per cent respectively (5). The obvious reason for low marketed surplus in case of small farms is low land-man ratio. As this ratio increases with the size of holdings, so does the marketed surplus.

The reason for inverse relationship between the marketed surplus and the size of holdings in case of cash crops is that the large farms employ more of hired labour and in part make their payments in kind. The small farms most of the time use family labour and have to make no wage payments. It is, however, to be kept in mind that this apparent inverse relationship holds only at the individual farm level. The quantities of cash crops received by labourers in payment of wages ultimately find their way to the market. For the agricultural sector as a whole the marketed surplus in respect of cash crops is not thus much affected by the size distribution of holdings. From the stand point of farm size distribution what remains important is, thus, the marketed surplus of foodgrains per unit of land or as a proportion of total production.

Production and Marketed Surplus

Although marketed surplus seems to be favouably affected by the increase in the farm aize, yet more important aspect of the problem is whether total marketed surplus from the farm sector will increase with the size distribution skewed in favour of larger farms. Larger holdings are normally and logically more market-oriented and make payments more in cash than in kind. Production (per unit) remaining the same more of the product-proportion is expected to pass through the market as the size distribution gets favourably skewed towards larger holdings. This is demonstrated so by the percentage of marketed surplus of various crops given in **table 1**, based on studies in economics of farm management in Punjab. Barring a few deviations, the data indicate that in general per cent marketed surplus increases with the size of the farm. Increase in the size of the farm, thus, has a positive influence on the marketed surplus as a proportion of total production. Farms below six hectares have a clear disadvantage that their marketed surplus is invariably below average. Farms between six to nine hectares remain marginally below average. It is only above 9 hectares that clear advantage start emerging.

Farm Size and Yields

Although marketed surplus increases with the size of the holdings and in consequence an increase in farm size might be accompanied by a larger per cent out-flow of agricultural commodities from the farm-sector, yet it may happen so at a reduced level of total production. It can thus reduce the absolute level of marketed surplus, if farm size holds a negative relationship with the production per unit of land. The data in **table 2** indicate that barring a few deviations, production per unit of land in general moves up with the size of the farm. Here largest farm-size group has advantage over the smaller farms, although 14-24 hectare group excells in case of cotton *desi* and maize. Farm size below six hectares is almost invariably at a disadvantage. If inexplicably abnormal figure of 43.91 for 1967-68 is ignored under 6-9 hectare group in respect of wheat 9-14 hectare farm-size group has clear advantage over farm below 9 hectares.

Table 1. Percentage of marketed surplus of various crops for different size groups, in Ferozepur district (Punjab), 1967-68 to 1969-70

Crops and Year	Holding size (Hectares)					
	Below 6	6—9	9—14	14—24	24 & above	Average
Mexican Wheat :						
1967—68	63.38	37.93	66.75	62.48	49.25	58.24
1968—69	49.97	48.14	49.76	37.45	44.40	44.23
1969—70	40.36	55.31	58.57	71.96	69.64	64.53
Average :	51.24	47.13	58.36	57.29	54.43	55.67
American Cotton :						
1967—68	96.69	90.23	90.07	75.17	95.50	90.89
1968—69	78.12	89.31	88.52	94.49	99.28	90.21
1969—70	88.46	93.51	96.90	94.69	99.51	96.42
Average :	87.76	91.02	91.83	88.12	98.10	92.51
Cotton *Desi*						
1967 68	68.44	95.08	59.60	70.51	99.50	75.15
1968—69	77.92	80.42	74.47	98.87	89.72	86.98
1969—70	86.11	85.46	94.38	79.50	95.05	86.29
Average :	77.49	86.99	76.15	82.96	94.76	82.81
Paddy						
1967—68	79.69	48.79	65.12	40.72	72.50	52.36
1968—69	94.17	95.25	64.93	69.06	88.00	66.40
1969—70	75.67	87.23	86.48	86.33	78.69	85.05
Average :	83.18	77.09	72.18	65.37	79.73	67.94
Maize *Desi*						
1967—68	49.16	48.54	67.29	32.03	99.58	51.93
1968—69	23.92	47.23	68.96	56.79	98.58	58.21
1969—70	36.86	65.14	51.76	59.21	49.93	56.34
Average :	36.65	53.64	62.67	49.34	82.69	55.49

Source : Compiled from Kahlon, A. S. & Surjit Singh, *Studies in Economics of Farm Management in Ferozepur district, Punjab* (Memeo.), Punjab Agricultural University, Ludhiana, 1967-68, 1968-69 & 1969-70.

Table 2. Average yield per hectare of different crops in Ferozepur district 1967-68 to 1969-70 (Quintals)

Crop and year	Holding Size (Hectares)					
	Below 6	6—9	9—14	14—24	24 & above	Average
Mexican Wheat						
1967—68	22.36	43.91	26.52	25.48	33.59	29.92
1968—69	20.14	21.02	21.04	21.46	28.95	22.46
1969—70	20.57	21.30	25.23	23.68	25.23	23.81
Average :	21.02	23.74	24.29	23.54	29.26	25.40
American Cotton						
1967—68	11.98	10.07	10.75	11.67	14.38	12.17
1968—69	9.09	8.38	8.20	9.31	8.84	8.83
1969—70	11.74	11.36	13.52	12.82	14.85	13.29
Average :	10.94	9.94	10.82	11.27	12.69	11.43
Cotton *Desi*						
1967—68	7.20	6.61	8.25	8.94	8.21	8.05
1968—69	7.81	8.30	8.20	7.73	8.21	8.07
1969—70	8.20	7.76	10.78	8.94	7.60	8.73
Average :	7.74	7.56	9.08	8.54	8.01	8.28
Maize *Desi*						
1967—68	14.06	13.51	12.33	14.39	10.72	13.29
1968—69	14.41	11.01	13.86	13.17	19.25	13.60
1969—70	13.10	13.73	10.27	11.45	6.49	12.11
Average :	13.86	12.75	12.15	13.00	12.15	13.00
Paddy						
1967—68	21.80	21.68	20.99	19.03	29.02	20.15
1968—69	29.87	23.23	20.92	25.86	30.80	24.91
1969—70	23.47	20.70	28.43	29.21	26.53	27.14
Average :	25.05	21.87	23.45	24.70	28.78	24.07

Sourse : Compiled from Kahlon, A. S. & Surjit Singh, ***Studies in Economics of Farm Management in Ferozepur district, Punjab*** (Memeo), Punjab Agricultural University, Ludhiana, 1967-68, 1968-69 & 1969-70.

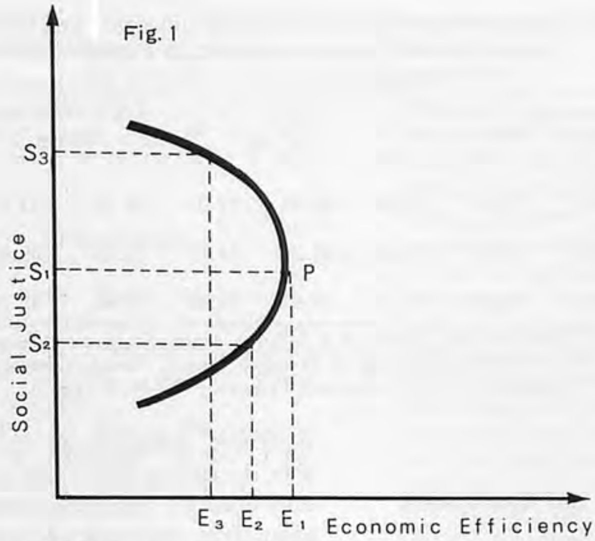
Table 1 and 2 suggest that as the farm size increases, the production per unit of land (yield per hectare) as well as marketed surplus as a proportion of total production increase togther. This suggests that farms below certain size (up to 9 hectares) are at a disadvantage compared to larger holdings of 14 hectares and above with respect to both yield per unit of land and per cent marketed surplus. **Table** 3 examines the problem a little further. This table indicates marketed surplus per acre on different sized farms. These figures have been obtained by multiplying each figure of yield for different crops over three years (**table** 2) by the corresponding figure in **table** 1 and dividing the product by hundred. Average figures in **table** 3 are the averages of the figures in the table. They have not been calculated from **table** 1 and 2. Marketed surplus per unit of land (in quintals per hectare) is the highest on holdings above 24 hectares. However, if we ignore the farms above 24 hectares as a typical because such farms are few in number and operate at different level of technology using all mechanized equipment, holding size 9-14 hectares (21.60 to 33.60 acres) gives the highest marketed surplus per unit of land.

How large the Holding

With respect to production per unit of land and per cent of marketed surplus to total production, and marketed surplus per unit of land, small farms below 6 hectares seem to be at a clear disadvantage.

That larger farms have an edge over small farms in terms of economic efficiency is also supported by two other studies in the Punjab. Sharma, based on his studies in Ferozepur district in 1967-68, estimated that scale economies in production of wheat were maximised at 48.28 acres, and for Mmerican cotton at 44.58 acres (10).

Singh in his study of the central plains of Punjab estimated that for a tractor-operated tubewell irrigated farm the net returns are maximized at 32.98 standard acres in non-bet areas and 38.05 standard acres in bet areas (9)[4]. Converted into ordinary acres the area works out to be 39.44 and 46.38 acres respectively.[5]



Economic Efficiency versus Social Justice

From the point of view of total production, per cent marketed surplus and marketed surplus per unit of land, as evidenced in the earlier sections, there seems to be a clear advantage on farms of the size 9-14 hectares and above. Small size farms (6 hectares and below) are at a disadvantage. If we ignore the farms above 24 hectares, which are very few in number and are at a different technological level using mechanized equipment farm size between 9-14 hectares or around average of 12 hectares (30 acres) seems to be the most efficient size. If the national objectives are that of increasing agricultural production and surpluses from agriculture, a set of policy incentives and disincentives as well as socio-economic framework needs to be provided to encourage medium-sized farms of the dimensions around 12 hectares or 30 acres of irrigated productive land.[6]

In addition to the criterion of economic efficiency, the size distribution has to however meet the test of social justice too, against the background of socialistic pattern of development envisaged by the Indian society in order to maximize the welfare of maximum number of people. Economic efficiency and social justice in respect of distribution of productive assets (land in this case) do not, however, go together throughout the distribution curve as illustrated in the **Fig. 1.**

In this diagram economic efficiency in the form of production and marketed surplus can be represented on horizontal axis. Social justice can be measured on vertical axis in the form of expanding the ownership base, i.e., the number of persons having control over productive assets (land in this case). Up to a certain point (P in the diagram) economic efficiency and social justice move in a complementary fashion. As the large estates get reduced in size, more number of people own the land assets and economic efficiency (in the form of production as well as marketed surplus) increases. In this phase more of labour subsitutes for capital. The Indian land reforms aimed at abolition of Zamindari and absentee landlords to the extent they were implemented to declare surplus lands above certain ceilings and distributed it among landless labourers and tenants, can be considered a

Table 3. Marketed surplus of various crops in quintals per hectare for different farm-size groups in Ferozepore districts, Punjab, 1967-68 to 1969-70

Crop and year	Holding size (Hectares)					
	Below 6	6—9	9—14	14—24	24 and above	Average
Mexican Wheat						
1967-68	14.17	16.65	17.75	15.91	16.54	17.43
1968-69	10.06	10.12	10.47	8.04	12.85	9.93
1969-70	8.30	11.78	14.78	17.04	17.57	15.36
Average:	10.84	12.85	14.33	13.66	15.65	14.24
American Cotton						
1967-68	11.58	9.09	9.68	8.77	13.73	11.06
1968-69	7.10	7.48	7.26	8.80	8.78	7.97
1969-70	10.39	10.62	13.10	12.14	14.78	12.81
Average:	9.69	9.06	10.01	9.90	12.43	10.61
Cotton Desi						
1967-68	4.93	6.28	4.92	6.30	8.17	6.05
1968-69	6.09	6.67	6.11	7.64	7.37	7.02
1969-70	7.06	6.63	10.17	7.11	7.22	7.53
Average:	6.03	6.53	7.07	7.02	7.59	6.87
Maize Desi						
1967-68	6.91	6.56	8.30	4.61	10.67	9.90
1968-69	3.45	5.20	9.56	7.48	18.98	7.92
1969-70	4.83	8.94	5.32	6.78	3.24	6.82
Average:	5.06	6.90	7.73	6.29	10.96	7.21
Paddy						
1967-68	17.37	10.58	13.67	7.75	21.04	10.55
1968-69	18.13	22.13	13.58	17.86	27.10	16.54
1969-70	17.76	18.06	24.59	25.22	20.88	23.08
Average:	21.09	16.92	17.28	16.94	23.01	16.72

Source: Compiled from Kahlon A.S., Surjit Singh, *Studies in Economics of Farm Management in Ferozepur district, Punjab,* 1967-78 to 1969-70.

move on this complementary phase of the curve.[7]

Viewed from the stand point of this theoretical construct and the empirical evidence produced earlier, ceilings on holdings at 30 standard acres, therefore, seem to be an appropriate level. As the point 'P' is reached (around 30 acres) on this distribution curve, further split of the land assets into smaller sized holdings tells upon the economic efficiency by way of reduced production and marketed surplus per unit of land. Beyond this point, social justice in the form of widening the land-ownership base thus runs counter to the objectives of economic efficiency. To reduce the ceilings below this limit might achieve some political and social objectives but will not be consistent with the objectives of economic efficiency. What is, therefore, pertinent at this stage is that exemptions on grounds of progressive farming, mechanization and other such considerations should not be allowed which provide loopholes for big landlords and estate owners to sidetrack the law stipulating ceilings on land holdings. This step is desirable from the point of view of social justice and cannot be rejected on grounds of even economic efficiency. Lowering of ceilings below 30 acres will be, however, clearly at the cost of economic efficiency.

Fig. 2

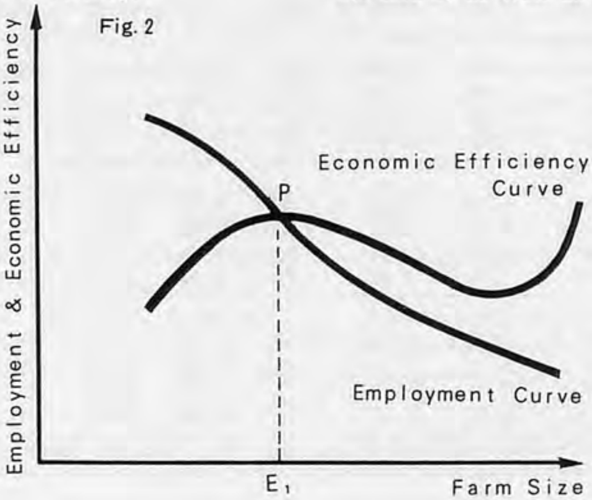


Table 4. Employment of Human Labour (in days) per cultivated hectare, Ferozepur district in Punjab, 1968-69 to 1969-70 (Average)

Category of Labour	Below 6	6—9	9—14	14—24	24 & above	Average
Family Labour	74.56	47.96	41.58	27.31	14.70	43.03
Hired Labour	29.39	36.65	42.27	44.31	39.16	39.02
Total Labour	103.93	84.61	83.85	71.62	53.86	82.05

Source: Complied from Kahlon, A.S. & Surjit Singh, *Studies in Economics of Farm Management in Ferozepur district, Punjab,* (Memeo) Punjab Agricultural University, Ludhiana, 1967-68, & 1969-70.

Farm Size and Employment

India being an agrarian society, employment of human labour becomes an outweighing consideration in any policy directed at accelerating the growth and development of agriculture. In the context of any land reform, therefore, employment needs to be examined as a function of farm size. Data in **table-4** brings out the picture in this regard. There is no doubt that as the farm size decreases employment per unit of land increases. This indicates that labour substitutes for capital on smaller holdings. There seems to be, therefore, a strong case for reduction in the size of the holdings, provided of course economic efficiency does not suffer. Since production and marketed surplus increase (**table 1,2 and 3**) as well as employment increases (**table-4**) as the farm size decreases below 24 hectares and upto 14 hectares, there is a case for imposing ceilings on holding at 30 standard acres without any exemptions or exceptions. To lower the ceilings below this point is, however, questionable, because it will increase employment only at the cost of economic efficiency as illustrated in **Fig. 2.** To the extent total production and marketed surplus per unit of the most scarce resource (land in case of India) increase, the increase in the farm size should be acceptable or reduction in form size leading to decreased productivity should not be acceptable, even if it may mean marginally lower employment.8) In this case per capita production and surpluses will be higher. Marketed surplus is bound to increase in this situation and more of capital will flow to non-farm sector, which can be used to enhance the capability of the non-farm sector to absorb surplus labour from agricultural sector. Overall total employment opportunities in the economy are thus likely to increase. With the possibilities of gainful employment outside of agriculture increasing, population burden on agriculture will decrease. Thus, agriculture can effectively contribute in the growth of the economy through its contribution by way of increased production and enhanced marketed surplus (capital flow to the non-agri. sector) providing a wherewithal for creation of gainful employment opportunities in the non-farm sector to absorb corresponding labour surpluses from the rulal sector. ■ ■

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(Notes)

1) Marketed surplus is that part of production which is actually brought to the market for sale. Marketable surplus is an other term, commonly used, which means the quantity that remains of the total production after consumption at the farm, including consumption by the farm family, seed requirements and payments made in kind. In the short-run, the marketed suplus can be equal to, greater or less than the marketable surplus due to forced sales, intention and capacity of farmers to hold the produce and expectations of future prices. In the long-run, however, both will tend to equality.

2) Economic efficiency and social justice have a limited connotation for the purpose of this analysis. From the view point of growth and development, agricultural surpluses are a crucial variable. Economic efficiency is therefore defined here as marketed surplus per unit of land (per hectare) as it would be determined by yield and per cent marketed surplus changes in response to changes in farm size distribution. Social justice for the purpose of this paper moves directly with the expansion of ownership base on land.

3) Numbers in parenthesis are citations of the references.

4) Standard acre is broadly defined as one irrigated acre ; fit for raising two crops a year, with more than average productivity and free from soil, water and other topographical problems (for details see Singh's "Homogenity of land in farm production Function", *Indian Journal of Agri. Sciences,* July, 1971. 'Bet' is defined as low-lying areas along side the river-beds.

5) Average conversion factor used by Singh is :
One Standard acre
=1.196 ordinary acres in non-bet area
=1.219 ordinary acres in Bet area.

6) No distinction between a standard acre and an ordinary acre has been made for these data, because of extensive irrigation, high soil fertility and two crops general possibilities in the study area.

7) Distribution of surplus land in fractions of acres to landless labourers and tenants is however questionable from the point of view of both economic efficiency and tangible social justice. For a detailed study on this subject see Gupta, H.S. (4).

8) For a further detailed discussion on this point see Johl, S.S. (6).

New Book

The universal trend toward intensive agriculture has created a need for practical information about crop protection equipment. The International Plant Protection Center has just published a MANUAL OF PESTICIDE APPLICATION EQUIPMENT to help meet that need.

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The Manual costs $4.00 US per copy surface postage paid from: *International Plant Protection Center,* Oregon State University, Corvallis, OR 97331/U.S.A.

Multiple Cropping and the Small Farmers

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Population continues to increase throughout the developing countries of Asia. The cultivatable land is already densely populated. The industrial and service sectors of many countries, although growing, are not generating employment as fast as the population is increasing. This means that the large majority of people must continue to derive their lively-hood from agriculture. Since unoccupied arable land is now nearly exhausted, land holdings per person can be expected to decrease. The critical problem facing many Asian countries is how to intensify cultivation and increase the standard of living on these already small and decreasing land holdings. Multiple cropping has the potential of helping attain this accomplishment.

Taiwan has illustrated the benefits of multiple cropping. Between 1915 and 1965 the multiple cropping ratio (i. e. the ratio of the total area planted each year to the area of cultivated land) in Taiwan rose from 1.32 to 1.98. During this 50 year period, the number of agricultural workers increased by 50 percent and the number of days worked by each person increased by about one third. The agricultural output worker also rose by 250% during this period (d'A Shaw, 1970). All of this put together means that the productivity and income per agricultural worker increased considerably.

To accomplish this in Taiwan, the multiple cropping ratio increased an average of 3.3% per year between 1945 and 1960 (Lee, 1971). Many Asian countries are presently at a critical point of over population, under production and under employment; and they must strive to attain a similar growth rate in the multiple cropping ratio.

The effective methods of increasing the multiple cropping ratio are (1) the introduction of improved varieties of crops, (2) irrigation, and (3) management of cultural practices and minimization of losses (i. e. selective mechanization).

The ability of farmers to utilize these improved methods varies with the size of land holdings and other variables. An analysis must therefore be made of the multiple cropping requirements and the capabilities of farmers before which planning policies can be formulated.

Improved Varieties

Improved varieties of rice have been bred with several characteristics that will help increase the multiple cropping ratio. Most importantly, the new varieties are mostly non-photo-period sensitive. Thus, they are less sensitive than traditional varieties to the length of daylight hours. Improved rice varieties can, therefore, be grown throughout the year in much of tropical Asia if sufficient water is available. Secondly, the new rice varieties have been bred to mature more quickly than traditional ones. Many traditional varieties require from 150 to 180 days to mature, while IRRI-8, as an example, will mature in 115 to 130 days, depending on the location and conditions under which it is cultivated. Some of the new rice varieties acclamated for India and Ceylon mature in only 90 to 100 days (d'A Shaw, 1970). The adoption of improved varieties, in the areas with sufficient water supply, has been very rapid. For example, in the Philippines the introduction of improved rice varieties developed by the International Rice Research Institute increased from 3% in 1967 to 33% in 1969. This introduction rate of a 30% increase in area in three years was greater than for any other country of Asia. The rate of increase in many other Asian countries is also proving to be very rapid. In 1967 the total area planted to improved rice varieties in South and South East Asia was 2.5 million acres (1.0

million ha.) while by 1969 the total had increased to 11.5 million acres (4.6 million ha.) a 460% increase in three years (IRRI Annual Report, 1969).

The impact of improved varieties on increasing the multiple cropping ratio cannot be separated from the plant management and cultural practices, namely; irrigation and selective mechanization. The improved varieties of rice will yeild more, if along with the modern inputs of fertilizer and insecticides, a controlled water supply is provided. Similarly, maximum land utilization through continous cropping may require the selective mechanization of some operations to reduce the unproductive land time between crops. The increased yields per crop and the increased crops per year, made possible by new plant varieties, are an integral part of the economic consideration for the management inputs of water, fertilizers, plant protection and selective mechanization.

A Case Study at Comilla, *Bangladesh*

The experiences in Comilla demonstrate that small farmers can adopt new varieties and practice multiple cropping. The rate of adoption of improved varieties of rice on irrigated land during the winter season in the Comilla Thana (County) of Bangladesh is shown in **Table 1.**

Table 1 shows that cooperative members adopted improved varieties one to two years ahead of non-cooperative farmers. The earlier adoption was expected as the improved varieties were first introduced through the cooperative organization. Within the cooperative membership, the larger farmers adopted improved varieties at a faster rate during the first two years than did the smaller farmers. By the fifth year, however, nearly all cooperative farmers used improved varieties on all their irrigated land during the winter season. The lag in adoption by the smaller cooperative farmers can probably be attributed to the assumed high risk growing newly introduced improved varieties. However, once it was demonstrated that the improved varieties could be successfully grown and that there were economic benefits to be derived from them, adoption by all cooperative members quickly followed.

Adoption of the improved rice varieties by non-cooperative farmers began when approximately 30% of the cooperative members had adopted. Once the advantages of improved varieties were established by cooperative members, the rate of adoption by non-cooperative farmers proceeded rapidly. Adoption went from 1% to 98% in only four years and reached the 98% level the same year that cooperative members reached that adoption level. It is interesting to note that the small non-cooperative farmers preceded the larger non-cooperative farmers in the adoption of the improved varieties. To summarize, the rate of adoption of new rice varieties for the winter season in Comilla proceeded very quickly, requiring only five years to reach almost complete adoption by all farmers.

The yields of improved varieties for different farm sizes in Comilla Thana, Bangladesh are show in **Table 2. Table 2** indicates that in only one year, 1970, was there a significant relationship between farm size and yeild. Even then, however, it was the farmers with .4 to 1.6 hectars (1 to 4 acres) whose yeilds were somewhat lower than the others.

In summary, it is evident that the small land holder with less than .4 hectares (1 acre) effectively competed in the production of improved varieties with larger land holders. Both the fast rate of adoption of improved varieties and the insignificant difference in yields between large and small farms indicated that farmers

Table 2. Average Yields of Improved Rice Varieties for Different Farm Sizes in Kg/ha.

Farm Size		Coop. Member Yield Kg/Ha *				Non Member Yield · Kg/Ha			
Ha.	(Acres)	1966	1967	1969	1970	1966	1967	1969	1970
0.0	(0.0)	—	—	4100	5430	—	—	4650	4140
0—.4	(0—1)	3580	2980	3670	4440	—	—	3180	3780
.4—.8	(1—2)	2380	4470	3970	4170	—	—	3420	4030
.8—1.2	(2—3)	4050	3160	4160	4000	—	—	4300	4190
1.2—1.6	(3—4)	2890	5160	4150	4190	—	—	3860	3630
over 1.6	(4+)	—	3120	4320	4900	—	3050	4550	4880
Average		3230	3990	4050	4430	—	3050	3710	4120
Level of Significance		.790	.255	.563	.010	—	—	.172	.059

* 1 Kg/Ha =0.89 lb/acre

Table 1. Percent of Rice Growers Using Improved Rice Varieties During the Winter Season in Comilla Thana, Bangladesh.

Farm Size		Cooperative Members Using Improved Varieties, %				Non-Cooperative Farmers Using Imporved Varieties, %			
Ha.	(Acres)	1966	1967	1969	1970	1966	1967	1969	1970
0.0	(0.0)	—	—	86	100	—	0	100	100
0—.4	(0—1)	5	13	83	97	0	0	92	100
.4—.8	(1—2)	6	21	37	100	0	0	58	95
.8—1.2	(2—3)	12	24	83	87	0	0	56	100
1.2—1.6	(3—4)	8	50	90	100	0	0	60	100
over 1.6	(4+)	0	71	91	100	0	13	40	93
Average		7	31	87	98		1	66	98

from no single land holding size were able to derive benefits from the improved varieties at the exclusion of the others.

Irrigation

Irrigation is one of the most successful methods of increasing cropping intensities. Irrigation allows the growing of additional crops during the dry (winter) seasons when the land would otherwise be fallow. In Bangladesh, for example, the multiple cropping ratio increased from 1.28 in 1960 to 1.42 in 1967, approximately 2% per year. Irrigation accounted for 40% of this increase. Irrigation by low lift pumps increased by 100% between 1967 and 1969, and the implementation of tubewells and large scale irrigation schemes can be expected to expand multiple cropping in Banglandesh in the years to come.

As multiple cropping through mechanized irrigation increases, care must be taken to insure that all segments of the rural population have equal opportunities to share in the benefits. Farmer cooperatives hold a great potential for equitably distributing the benefits of irrigation. Bangladesh illustrated the successful application of cooperative irrigation where land holdings are small and fragmented (average farm size is less than 1.2 hectares or 3 acres). These small farmers lacked the financial resources to install, maintain and operate thier own individual irrigation systems. In the Comilla Thana, the farmers organized themselves into primary village cooperative societies in order to obtain irrigation facilities. These societies requested irrigation facilities from the central cooperative association. The irrigation facility took the form of low lift pumps where surface water was available or deep tubewells where surface water did not exist. The societies were responsible for digging and maintaining channels for the distribution of the irrigation water as well as for setting up a procedure for sharing the water among its members. The irrigation pumps or wells were rented by the cooperative societies from central cooperative association. The central cooperative had the responsibility of repairing and maintaining the pumps, as well as training operators and maintenance personnel. Although the pumps were rented to the village cooperative societies, use of the water was not limited to cooperative members. Often persons who were not members, but who had land within the area which could be irrigated by the pump, purchased irrigation water from the pump group.

Table 3 gives, for the total number of persons growing irrigated crops each year in the Comilla Thana (County) of Bangladesh, a percentage estimate of how many were in each land holding size. Ideally, irrigation benefits should be derived equally by persons of all farm sizes, thus the percentage values for each year given under heading 3 of **Table 3** should equal the values for the respective farm size given under heading 2. Similarly, for non-members, valuse under heading 5 should equal those under heading 4. It can be seen from **Table 3** that for cooperative members, farm size had a negligible effect on who was able to grow a crop. Thus, the cooperatives were successful in distributing the benefits of winter irrigation among all of their members regardless of farm size.

Unfortunately, this was not the case for non-members. While over 65% of the non-members had less than .4 hectare (1 acre) of land or were landless, no more than 31% of the persons who were able to use irrigation to increase their multiple cropping ratio in any one year came from this farm size. Thus, in order for the farmers with less than .4 hectare (1 acre) to gain the benefits of irrigation they needed to belong to a cooperative society. Cooperative membership, however, required compulsory savings and share purchases. Under traditional farming conditions about .4 hectare (1 acre) was required to support a family of four at a subsistance level. Even assuming no costs of production other than what the family could provide, most farmers with less than this acreage were unable to make savings or share purchases and were thus excluded from cooperative membership. With the introduction of irrigation and improved varieties of rice to increase the multiple cropping ratio, this same family of four could be supported on less than 0.35 hectare (.85 acre) of land, even if costs of production were assumed to be 45% of the total value of the crop produced. Thus, the introduction of irrigation to increase the multiple cropping ratio had the effect of decreasing the farm size needed for subsis-

Table 3. Representation by Farm Size of the Number of Persons Growing Winter Crops.

(1)		(2)	(3)				(4)	(5)			
Farm size, hectares	(acres)	% coop-mem with given farm size	Of members growing winter crop, % with given farm size				%non-mem. with given farm size	Of non-members grow winter crop, % with given farm size			
			1966	1967	1969	1970		1966	1967	1969	1970
		2	—	—	3	2	24	—	2	7	4
0—.4	(0—1)	12	22	11	11	18	41	16	23	22	27
.4—.8	(1—2)	43	36	33	41	32	13	41	42	32	22
.8—1.2	(2—3)	18	19	29	11	11	12	30	20	15	26
1.2—2.0	(3—5)	16	19	18	24	19	7	13	10	24	15
over 2	(5+)	8	3	8	8	18	3	3	2	2	5

tance. This meant that through multiple cropping many more people were made eligible for co-operative membership and could expect to have a viable farm even though they owned less than .4 hectares (1 acre) of land.

Selective Mechanization

The selective mechanization of certain cultural practices for crop production can substantially increases the multiple cropping ratio. For example, in a survey of 50 farms in West Pakistan, farms which used only animals for tillage had a multiple cropping ratio of 1.44 while farms using tractors for tillage had a ratio of 1.68 (Ahmad, 1972). Tractors, in this case, were associated with an increased multiple cropping ratio of at least 17%.

Land use efficiency may be increased by mechanizing any of the operations such as harvesting, threshing, tillage, fertilizer application, and planting which occur between the harvesting of one crop and the planting of the next. Most of these operations can, however, be accomplished just as quickly by large groups of people in countries and areas where abundant labor is available. Where this is possible, labor intensive methods should be used to prevent unemployment and possible displacement of rural people. For example, in many Asian countries, harvesting is performed by groups of hired laborers whose major income for the year may be that derived during the harvest period. In Bangladesh, where about 15% of the rural population was landless in 1969, the harvesting and threshing operations utilized 32% of the labor which was hired for the production of rice. Transplanting utilized 28% of the hired labor used for rice production. Thus these three operations accounted for 60% of the labor which was hired. Some mechanization which would reduce the hired labor employed in these operations would seem undesirable, as long as there was an absense of alternative employment for these landless laborers. Primary tillage might be an exception because of the excessive energy requirements.

The tillage operation in Comilla accounted for only 2% of the labor hired for rice production. A simulation model indicated that in Bangladesh where one crop can immediately follow another and two to four persons are hired for the harvesting, threshing, and transplanting operations; tillage using animals can account for over 50% of the non-productive time between harvesting one crop and planting the next. Mechanical power to supplement animal power for the tillage operation, can reduce tillage time by 60% and the total time between crops by 32% (Esmay, et al, 1970).

As with irrigation, it is desirable to analyze the effect of tractor tillage on the small farmer. In the Comilla Thana only 8.2% of the farmers with less than .4 hectare (1 acre) and 26% of the .4 to .8 hectare (1 to 2 acres) farmers owned a pair of bullocks in 1964. In response to this power shortage for the tillage operation a centrally located cooperative tractor station was established which rented 35 Hp tractors on a daily basis to groups of farmers through their local village cooperatives. The effective use of cooperative tractor mechanization by small farmers is indicated by the tractor use during the irrigation seasons from 1966 to 1969. Over 57% of all tractor users in these years had farms of less than .8 hectars (2 acres). In addition, farmers without bullocks who used the tractors for tillage planted a crop on 60% of their land, while those who rented bullocks for tillage planted a crop on only 47% of their crop land. For farmers who owned bullocks, the proportion of their farms which was cropped was nearly equal when bullocks were used for tillage (48%), as when tractors supplemented the bullocks (49%). Thus the tractors were of benefit to the small farmer without bullocks by increasing their multiple cropping ratio, while not giving this same advantage to larger farmers with bullocks. Thus cooperative tractor mechanization had the potential for both increasing the multiple cropping of the small farmer and allowing him to compete more successfully with the larger land owners.

Conclusion

The objective of agricultural development programs in many of the developing countries of Asia is to increase total agricultural production and the standard of living in the rural areas. The results of this Comilla case study indicate that irrigation, mechanization, and the use of improved plant varieties all may contribute to multiple cropping and increased total production. More importantly, however, is the ability of the very small farmers, those with less than .4 hectares (1 acre) of land, to effectively utilize these improved methods to increase their multiple cropping ratios and their levels of living. These small farmers were only able to realize all of these benefits through specialized organizations such as farmer cooperatives. Cooperative organizations have limitations, but without them small farmers have little potential for improving their subsistance level of existence. Thus, rural development planners in the countries of Asia must include the small farmers in the agricultural modernization plans. ■ ■

(References are on p.88)

Tractor Custom Hire Services in Multiple Crop Farming

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Custom hire tractor service is an organizational means by which farmers with small holdings may use mechanical power from large, efficient tractors, while paying only a small charge per unit of work done. Thess same farmers, because of their small land holdings, tend to be among the first to want to increase the intensity of agricultural production on their land. Multiple cropping is one of the most direct and productive means for achieving this.

Multiple Cropping on Farms Hiring Custom Tractor Service

A survey of tractor hire services was conducted in 1968 and 1969 in Thailand and Malaysia*. This survey revealed that:

1) Farmers using multiple cropping tended to have,
   a) greater need for tractor service
   b) greater funds available to pay for tractor service
2) Farmers hiring tractor service had, subsequent to adoption of tractor tillage, more available labor time which could be devoted to multiple cropping.
3) Farmers hiring tractor service felt the need to increase their income to meet the added cost of this service.

Sixty-nine farmers in Thailand and 63 farmers in Malaysia who were interviewed reported 118 and 109 income-increasing activities, respectively, that they were able to undertake subsequent to the hiring of tractor service. These activities were categorized on a table.

Increases of cropping intensity were mainly of two types. One was the planting of crops, such as orchards, sugarcane, and cassava, which occupied the land all year and required considerable amounts of the cultivator's attention. The second type was an increase in the number of short-duration crops harvested each year from a given piece of land (multiple cropping). The following table shows the incidence of multiple cropping among farmers interviewed in the above survey who hired tractor service or who owned tractors. Some of them, however, had been practicing multiple cropping before their use of tractor or power.

The fact that higher proportions of farmers in Malaysia, relative to those in Thailand, were practicing multiple cropping, was due mainly to the emphasis in Malaysia on double cropping of rice, and irrigation development for that purpose. Also, farm size in Malaysia was smaller and land less easily available, resulting in more interest in increasing income per unit area.

Vegetable crops frequently required many cultural operations. Therefore, farmers tended to use only small acreages of vegetables in their multiple cropping sequence, so that the available labor would be sufficient for those operations on the acreage planted. Thus, primary tillage re-

Percent of Income-Increasing Activities Mentioned

Activity	Thailand	Malaysia
Increased production on land owned originally	65	75
	(of which)	(of which)
Increased cropping intensity	(38)	(40)
Increased noncrop production (such as animal production etc.)	(27)	(35)
Application of work to additional land	25	13
Work in urban jobs	8	9
None	2	3

	Percentage of Farmers Interviewed			
	Thailand		Malaysia	
Number of farmers interviewed	Farmers Hiring Tractors (69)	Farmers Owning Tractors (62)	Farmers Hiring Tractors (63)	Farmers Owning Tractors (42)
Multiple cropping on all annual crop acreage	25%	29%	59%	45%
Multiple cropping on part of annual crop acreage	20	11	9	14
Total using multiple cropping on annual crop acreage	45	40	68	59
Farmers, in the above total, growing vegetables in multiple cropping sequence	13	8	3	0

quirements for the small areas devoted to multiple cropping with vegetables were considered sufficiently minor that they could be handled with traditional methods.

Since tractors offered economic and operational advantages mainly in tillage work, the desirability of tractor use in multiple cropping with field crops on extensive acreages was considered greater than that of tractor use on limited acreages of vegetable crops. Consequently, tractor power generally was not widely used in the preparation of soil for vegetable crops in multiple cropping sequences. In the case of multiple field crops, however, time constraints between the harvesting of one crop and the planting of the next made the use of tractor power for tillage of the full farm acreage advantageous from the standpoint of speed of work accomplishment, as well as from that of economics. In some instances, such as in the doudle cropping of rice, tractor tillage was usually considered essential. Thus tractor power was specifically linked to the expansion of multiple cropping with field crops. In Thailand, the most common of such arrangements were the maize-beans or the maize-cotton sequences. In Malaysia, it was double cropping of rice thatwas linked to the use of tractor power.

The advent of increased cropping intensity increased the incidence of production of upland row crops. Of the farmers interviewed who hired tractor service for tillage, 12 percent in Thailand and 5 percent in Malaysia wished that they could also hire tractor service for interrow cultivation. The use of large tractors for such cultivation is complicated in these areas by the need for rows to be spaced accurately and uniformly. This usually requires a planter of the same width as the tractor cultivator; and the timing of tractor availability with the desired planting date is difficult in a system of tractor hire services, when tractors are moving about within extensive areas. In addition, upland crop areas (especially those recently cleared) frequently contain stumps, roots, etc. which would impede the progress of large tractors when they must follow the path of crop rows. In Thailand, tractor hire service for interrow cultivation of maize, cotton, and sugarcane was available in certain localities from owners of power tillers, or single-axle 2-wheel tractors fitted with drum rotors instead of wheels **(Fig. 1)**. This type of equipment does not depend on high accuracy of row spacing, and the lighter units can detour around obstructions without causing undue crop damage.

Potential Development for Multiple Cropping Using Tractor Hire Service

In many rice-growing areas of Southeast Asia, rainfall is high and surface slopes are almost nonexistent. Thus rice is frequently the only crop grown, and it is grown only once per year if

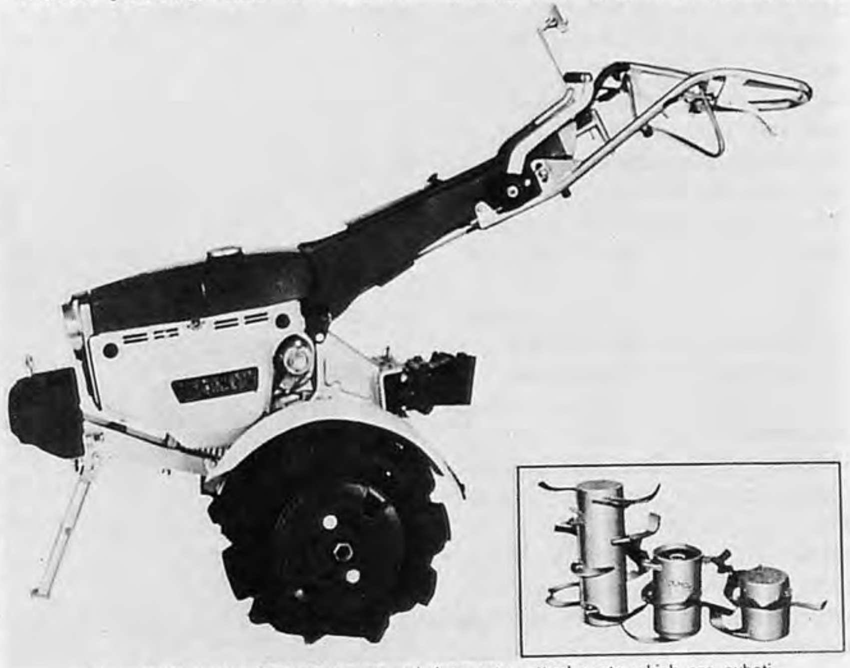

Figure 1. Single-axle 2-wheel tractor and drum rotor attachments which are substituted for the wheels when the machine is used for interrow cultivation of upland row crops.

Figure 2. Four-wheel tractor with a conventional ridger.

adequate year-round irrigation is not available. In these areas there is potential for multiple cropping using either field crops or vegetables. In a number of areas, crops like sorghum could be grown on rice soil even if no irrigation was provided, and little or no rain fell after rice harvest.

The agronomic practice which permits the growing of other crops in lowland rice fields is the forming of raised ridges or beds, with interspaced furrows for drainage. The main obstacale to this practice is the sizable energy requirement for soil movement to produce the alternate beds and furrows, and to level the field again for rice production. Low-cost energy available with tractor usage is ideally suited to these tasks. Conventional 4-wheel tractors can use ridgers **(Fig. 2)** or border disc attachments **(Fig. 3)** to form the beds or ridges, and disc harrows or grader blades to reconstruct the level field surface.

Power tillers and single-axle 2-wheel tractors can also be used for formation of beds and furrows if spiral rotor or ridger attachments are used. The re-leveling of the field can be done using spiral rotor attachments, but this operation tends to be more difficult with the 2-wheel units than with 4-wheel tractors, which can develop the traction required to move sizable quantities of soil.

Summary

Increases in multiple cropping on small acreage farms in Southeast Asia, and the use of tractor custom hire services on these farms, are mutually complementary steps in agricultural development.

Tractor power appears best suited to tillage operations for the field crops in the multiple-cropping sequence.

Further potential for simultaneous development of multiple cropping and tractor power use appears to lie in low-land rice areas. There other crops can be planted after rice harvest if tractors can economically produce alternate ridges and furrows in the field surface, and subsequently produce a level field surface once the off-season crop had been harvested. ■ ■

* Survey of Tractor Contractor Operations in Thailand and Malaysia, by W. J. Chancellor, Ag. Eng. Dept., Univ. of Calif., Davis, Calif., USA, August, 1970. See also, The Tractor Contractor System in Southeast Asia and the Suitability of Imported Equipment by W. J. Chancellor, *Agricultural Mechanization in Southeast Asia,* Vol. 1, No. 1, Spring 1971.

Figure3. Border disc attachment for constructing and maintaining ridges and furrows.

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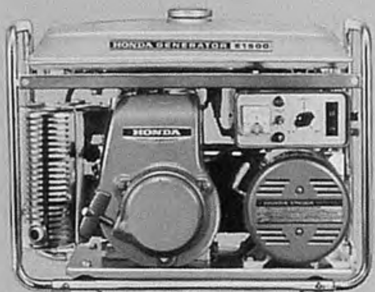

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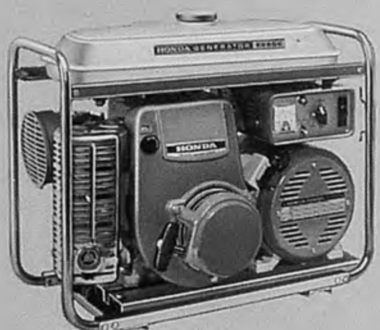

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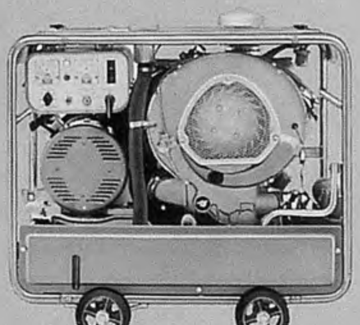

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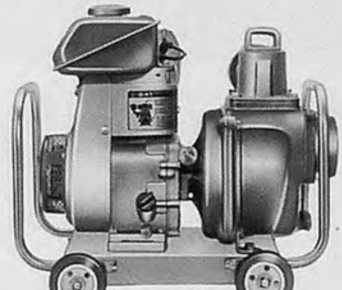

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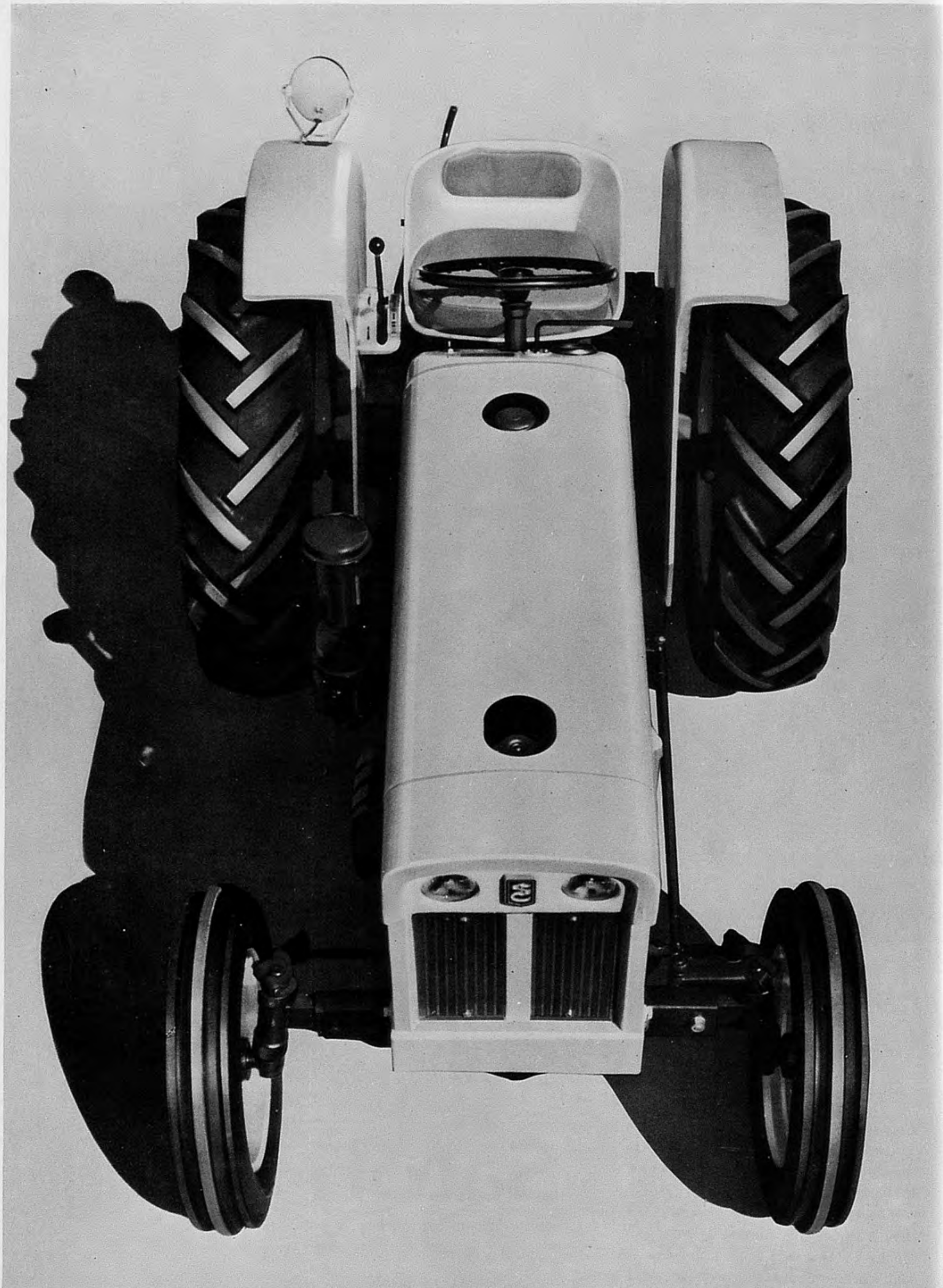


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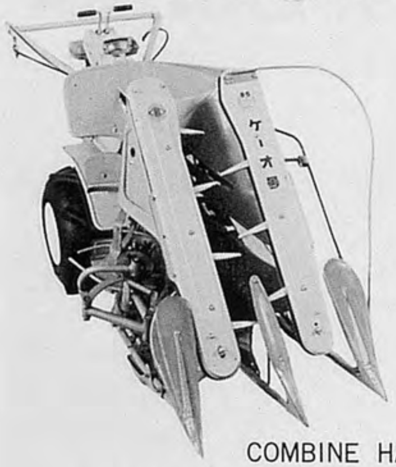

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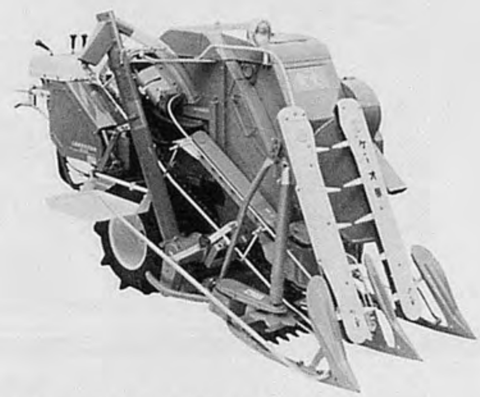

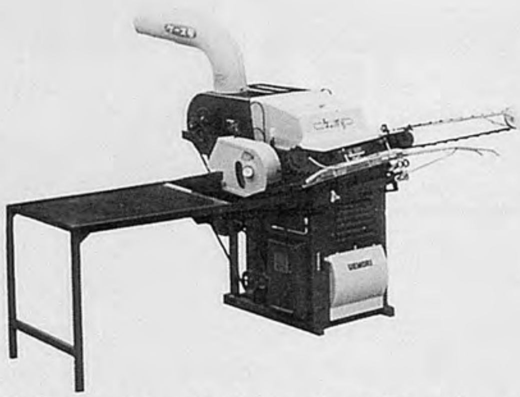

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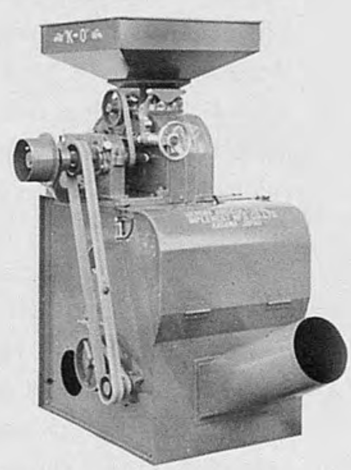

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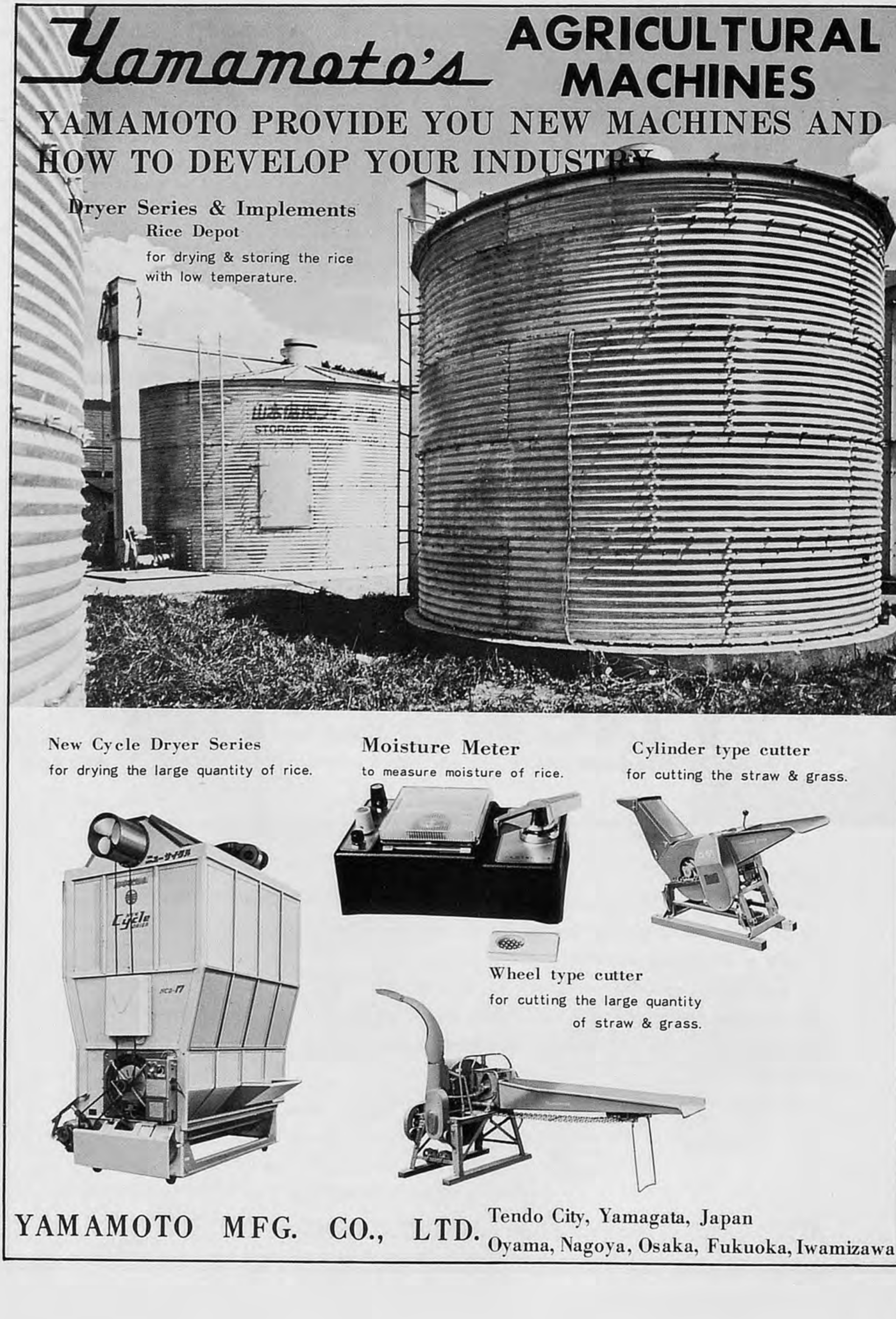
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A System for Selection of Agricultural Machinery

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Introduction

For many years there has been a continuing interest in mechanizing agriculture throughout the world. Each nation has viewed the problem somewhat differently. Some have been primarily concerned with mechanization of commercial crops utilized in international trade. Other countries have attempted to mechanize primarily the sector of agriculture devoted to domestic food production. In either event, machinery selection is a vital question.

Since in many cases mechanization of agriculture can be achieved only through government subsidy, an agency of the national government usually will be given the responsibility of choosing the types of equipment and the specific sizes and makes that will be available within a country. A companion paper (Harris and Bender, 2) discusses the types of information needed in order to make decisions with regard to machinery selection. This paper indicates an approach to machinery selection that planning agencies should consider with the assumption that the needed data are available.

Since the decision made by a national planning agency regarding what types of farm machinery will be available within a country will affect a large segment of both the rural and urban population, it is imperative that the available choices be carefully evaluated well in advance of the commitment of funds and the initialization of a mechanization program. Although it is recognized that not everything can be foreseen, careful planning and machinery selection may reduce economic dislocations to a considerable degree.

Decision-Makers within the Economy

Currently where alternative pieces of equipment are evaluated, the benefits and the costs which the economy will incur as a result of the introduction of such equipment are estimated in order to determine whether or not such equipment will result in a net gain or loss to the total economy. (Such benefit-cost analyses and related procedures are discussed at length by Prest and Turvey, 4.)

We are not concerned here with the relative merits of benefit/cost ratios, measures of the internal rate of return of an investment effort or the other measure of the impact on society of a specific investment (in this case agricultural machinery). On the contrary, as measures of the net welfare gain to a society these are valuable criteria with each yielding a slightly different perspective. *In toto*, they enable national planners to weigh the merits of competing investments and establish priorities.

The concern in this paper is the implicit assumption that farmers will adopt a specific piece of equipment if it is available within a country. In effect, this implicit assumption states either that farmers do not make economic decisions or that the adoption of the machine will be profitable to farmers. Usually, the second alternative is the assumed position. However, this assumption is rarely examined as critically as it deserves to be.

The remainder of this paper describes an analytical approach that has as its central thesis the decision making role of the farmer. Such an analysis will enable national planning agencies to evaluate alternative pieces of equipment in light of their desirability from the standpoint of the farmers who will purchase and use them. This procedure coupled with the traditional analysis of national benefit and cost could greatly enhance the gain to a country from the introduction of a specific set of agricultural equipment.

The Suggested Analytical Approach

The central structure of the analytical approach proposed in this paper is a linear programming model of the typical farm. Linear programming is a well-known optimizing technique which has been widely used with considerable success. Two exceptionally readable references are Heady and Candler (3) and Daellenbach and Bell (1).

In order to utilize this analytical technique, it would be necessary first to delineate all of the types of farms to be analyzed. For example, it may be necessary to group farms only according to size. On the other hand if climate varies within the country or region that will be mechanized, it may be necessary to consider region as well as farm size since different crops will be grown and different types of equipment may be needed. As an illustration, it may be determined that the following categories are required for analysis: (see **table 1**).

Table 1. Farm categories to be analyzed

Temperate Climate Main Crop						Tropical Climate Main Crop					
Rice Farm Size			Wheat Farm Size			Rice Farm Size			Sugar Cane Farm Size		
0~1ha	1~2ha	2~ha	0~1ha	1~2ha	2~ha	0~1ha	1~2ha	2~ha	0~1ha	1~2ha	2~ha

This simple chart indicates that there are twelve types of farms to be analyzed. The first difficulty in an analysis of this type is the potential of being inundated with information. Extreme caution must be exercised to keep the number of categories within a manageable range. For example, the judgment that farms of less than one hectare cannot be economically mechanized would permit elimination of four categories from further consideration.

Once the farm categories have been determined, it is necessary to build a linear programming model of each one. A great deal of care must be exercised in the development of a linear programming model. Ordinarily, the construction of the model must begin by determining the options that the farmer has available to him. In such a determination it usually is desirable to include alternatives which are not currently practiced as well as those that are. For example, a partial listing of the alternatives available to a Rice Farmer in a temperate climate with 1~2 hectares of land (taken from **Table 1**) may be as follows:

1. Rent out his land
2. Hire out his labor to non-farm employment
3. Grow rice by hand without animal power
4. Grow rice with animal power
5. Grow rice with a 5 hp gasoline power tiller
6. Grow rice with an 8 hp diesel power tiller
7. Grow rice with an 8 hp kerosene power tiller
8. Grow rice with a 10 hp kerosene power tiller
9. Grow rice with a 10 hp diesel power tiller

10…16. Grow another crop with the production methods listed in 3~9

17…21. Use power source listed in 5~9 to generate electricity

22…26. Use power source listed in 5~9 to pump water

27…31. Use power source listed in 5~9 to haul freight

et cetera

Once the alternative actions that the farmer can take have been delineated, it is necessary to list the factors that limit his actions. Some of these constraints will restrict his actions in a general way. For example, credit availability (or lack of it) may restrict the farmer to traditional production methods even though mechanization would be profitable at market interest rates. Other constraints may be very specific. For example, timeliness of operations may create severe demands for labor at certain times of the year. Such a constraint may restrict the area that can be farmed with traditional methods but may not be as restrictive when machinery is utilized to perform functional operations in less time (e.g., harvesting or planting).

Another example of such specific restrictions would be weather conditions which may permit traditional hand methods of production to continue when machines cannot enter the fields.

All of the relevant constraints must be ascertained and incorporated into the linear progrmming model. This aspect of the analysis is essential. One of the best ways to test whether or not a relevant constraint is missing is to run several solutions of the model to determine the profit maximizing answers. These should then be evaluated by knowledgeable experts to ascertain how reasonable the linear programming solutions are. If the solutions are unreasonable, it is because a relevant constraint was omitted. The constraint will need to be defined and the analyses rerun. This sort of give-and-take between the computer solutions and knowledgeable individuals is essential to building realistic, useable models.

Once a realistic model of a farmer and his decisions is available, the analysis of alternative government policies is possible. For example, suppose that the computer solution resulted in farmers purchasing 10 horse-

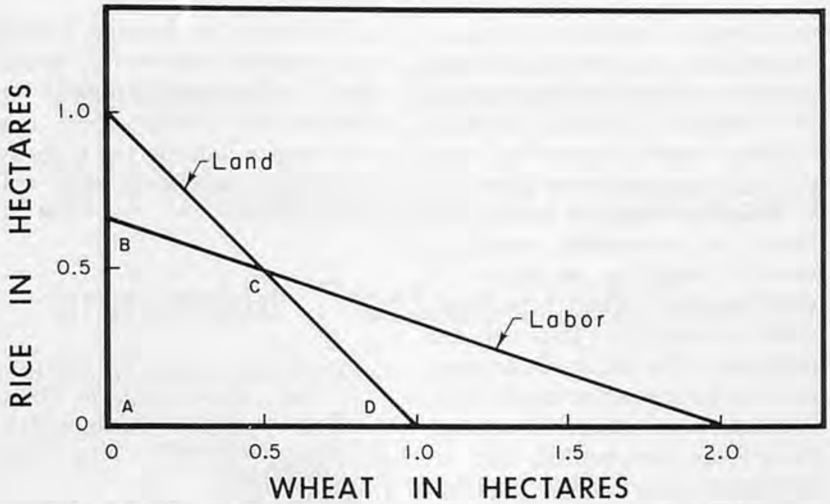

Figure 1. Alternative production of rice and wheat as limited by available land and labor.

power diesel power tillers. It may be that from the standpoint of national policy that this is undesirable because of a non-agricultural consideration (e.g., diesel power tillers must be imported). In such a case, a special tax may be considered to shift farmers to a different power tiller. The linear programming model could be used to determine the amount of the tax necessary to achieve such a shift, the resultant economic impact on farmers, and the power source that they would subsequently choose. In this way, a national planning agency could evaluate the impact on farmers of a variety of governmental policies.

After these analyses have been performed and it has been determined how farmers will react (i.e., what crops they will produce, what types of machinery they will purchase, etc.) it is necessary to incorporate these data into the traditional benefit-cost analyses that are used to evalutate a project (such as farm mechanization) from the standpoint of national welfare.

A Simple Illustration of the Model

It is readily apparent that in actual fact the national planning agency is faced with such a wealth of alternative means of production and constraints upon those means that the number of choices is staggering. Linear programming is a mathematical tool designed to aid decision makers where large numbers of possibilities exist with various kinds of constraints within which a final decision must be made.

In order to illustrate how linear programming aids in this decision process, consider the following simple problem which uses hypothetical values which were chosen for clarity of presentation:

A farmer has one hectare of land and 2000 hours of family labor. He can plant rice or wheat. It takes 3000 hours of labor to produce a hectare of rice and 1000 hours of labor to produce a hectare of wheat. A hectare of rice yields a profit of $200. A hectare of wheat yields a profit of only $100.

How much rice and wheat should the farmer produce in order to maximize profit?

In **Figure 1**, the problem is shown in graphical form. With rice measured on the vertical axis and wheat measured on the horizontal axis, we are able to draw boundaries showing all of the possible combinations of rice and wheat that the farmer can produce. That is, the farmer can produce no wheat or rice (point A), no wheat but 2/3 hectare of rice (point B), 1/2 hectare of wheat and 1/2 hectare of rice (point C), 1 hectare of wheat and no rice (point D) or any of the points that lie within the figure ABCD.

The mathematicians that developed linear programming as a technique proved that only corners of a figure such as ABCD are of interest. Therefore, we can evaluate the profit at each of these four points and choose the one which maximizes profit. **Table 2** shows the results of these calculations.

In this case the maximum profit is at point C with the production of 1/2 hectare of rice and 1/2 hectare wheat. This is true in spite of the fact that rice has double the profit of wheat. In addition, we could learn through trial and error that increasing the profit from rice would not change the point of maximum profit until rice yielded a profit greater than $300 per hectare at which point, the farmer would produce 2/3 hectare of rice and would have 1/3 hectare of land idle.

By this means we could determine what farmers should be expected to produce. In addition, we could test the usefulness of various government policies that might be under consideration. For instance, a policy to increase rice production because profit per hectare would increase by $50 would not be effective in our hypothetical problem because the point of maximum profit would still be point C and production would remain unchanged.

Table 2. Profit yielded by the different production plans.

Point in Figure 1.	Hectares of wheat	Hectares of rice	Profit in dollars
A	0	0	0
B	0	2/3	133 1/3
C	1/2	1/2	150
D	1	0	100

As was shown earlier in this paper the alternatives faced by farmers and the constraints within which decisions must be made are far more complex than the simple illustration that we have just presented. However, the concept is unchanged. As the size and complexity of the problem grows, we no longer use graphs but a system of equations and a computer to solve that system. Throughout the analysis the concept is still that of delineating the feasible alternatives that exist and searching among these to find the best decision.

Data Needs of a Linear Programming Model

As is evident in the above discussion, using linear programming models of typical farms in order to determine the impact of various government policies requires a great deal of reliable data. In addition to the detailed performance data advocated in a companion paper by Harris and Bender (2), it is necessary to have input-output relationships by season of the year, by type of activity and with their associated costs.

In other words, these detailed production budgets must not only define how many hours it takes to prepare a seedbed (i.e., a specific value in terms of production performance), but the days or the weeks in the year when this specific task can be performed. The timing of operations becomes essential because this is a constraint within which the farmer must make his decisions. Consequently, it must be included in the linear programming model.

Coupled with these detailed physical relationships there is an equal need for detailed cost data especially for operating costs. As a result fuel consumption, use of lubricants, down times, repairs, etc. should be developed for operating machinery under various kinds of conditions (summer, winter, rain, etc.) for the different activities that will be included in the analysis (plowing, planting, hauling freight, harvesting, etc.). Although engineers are often able to estimate many of these costs based on theoretical considerations, it would be an important step forward if such cost data were systematically collected and published. If a facility is developed to measure performance data, it should be expanded in concept to develop the needed cost information as well. Detailed information concerning the timeliness of operations under field conditions would probably have to be developed in the field although many trials and experiments could be performed by the same agency that had the responsibility of developing performance and cost data.

Summary and Conclusions

This paper has presented an analytical approach to analyzing problems of farm mechanization. The procedure advocated is the construction of linear programming models of typical farms in order to determine the probable response of farmers to various alternatives available to them and the different governmental policies that may be adopted.

This procedure does not replace the traditional methods of benefit – cost analysis that are currently used to evaluate investment projects. On the contrary, this approach is simply another step that needs to be inserted into the overall analysis. It provides a planning agency with a better indication of how farmers will behave and the likelihood of success from the standpoint of farmers adopting specific types of equipment.

As a result, the authors urge that future benefit – cost analysis include linear programming models of farmer decision-making. However, before such models could provide meaningful results, it will be necessary to begin to systematically collect cost and performance data on the types of agricultural equipment that will be considered. ■ ■

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History of the Development and Classification of Japanese Power Tillers and Hand Tractors of Multipurpose Performance

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Preface

Generally speaking, "Hand Tractor" is a machine composed of an engine with a driving mechanism and is sometimes called a walking type tractor, while "Power Tiller" is a hand tractor with some tillage equipment. In Japan we sometimes call all of "Power Tillers", *Kounki* in Japanese.

One of important principles in using agricultural machinery is to drive it as many hours as the owner can, for productive farm works, in order to be paid back and produce more value than the original investment to purchase the machine.

This means that, the owners of hand tractors or power tillers have to possess correct idea of their multipurpose performance.

It is also useful for the engineers who wish to develop a new hand tractor or power tiller, to know conceptional basic character of its multipurpose performance including knowledge about attachments.

Although there are many types and models from manufactures, they can be separated into several groups depending on the basic character of their performance, especially for multipurpose farm works.

In China, there is a famous proverb which is also used in Japan that, "Visit old one, know new one".

To know the history of Japanese hand tractors and power tillers is one of the useful ways to know new ones.

In this print, a brief history will be described in order to have better understanding of multipurpose performance of the machine, how and why these machines were developed.

A. Brief History of Japanese Hand Tractors and Power Tillers

About 50 years ago (Around 1920), western garden tractors of walking type···Utiliter from the United States and Simer from Switzerland etc,···were imported into Japan.[1,2] These machines were carefully tested for their adaptability to different farming conditions in Japan, from that in western countries. Utiliter and Simer are the mother of Japanese Power Tillers.[1,3,4] (refer to **Fig.** 1).

About 15 years passed as a testing, remaking and/or developing term for the machines including attachments, to suit to Japanese local farming conditions of mainly narrow paddy rice fields and wheat or barley cultivation for second crop and so forth.

About 1935, local made hand tractors had their first appearance into the market, and were mainly used for shallow preparatory tillage or inter-row-cultivation on upland fields.

These hand tractors were coupled tightly by bolts with its

Silhouette of Simar (1921)

Silhouette of Utilita (1921)

Fig.1 (Source; photograph in *Agricultural Engineering Manual*, Tokyo Univ., 1951, p. 545)

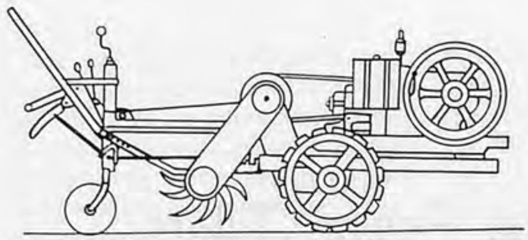
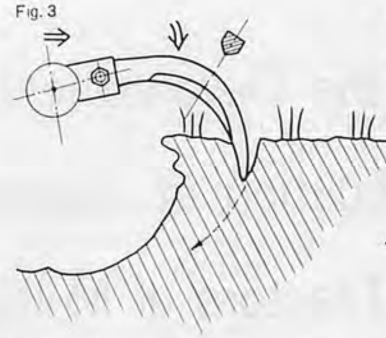
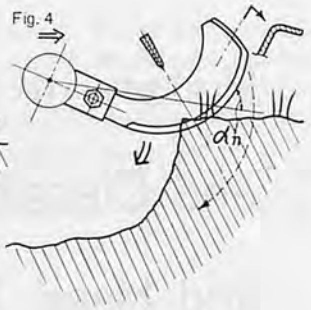


Fig.2 (Source; photograph of T. Nihei, *Story of Old Farmtools*, 1972, p. 204)





tilling device (mainly rotary cultivator), and its drive wheels made of iron could not be changed to other type of wheels.

Fig. 2 shows a typical style of one of them in around 1940 to 1950.[10] Engine ps was 3.5 to 5 ps.[10] These machines could not be used for puddling because of poor sealing technology against dust, water and oil, low traficability of wheel mechanism and also poor efficiency of rotary tiller.

Namely, the machine was a specialized one only for tilling soil without utility, except using as prime movers or source of power to drive a stationary machines. These machines were widely used by the contractors for rough tillage before planting. This heavy work requested long life mechanism which should be surely paid back, resulting to the great advancement of power tiller mechanism.

At that time, cultivation done by animal power was still usual, and plowing depth was commonly 10 to 12cm. In 1948, total animal power···draft horses and cows···was 1,450,000 ps and total power of tractors was only 30,000 ps.[5]

World War II caused lack of foods in the country, and agricultural specialists began to spread the slogan of "Deeper plowing, higher yield".

This slogan encouraged to develop not only unique Japanese plows but also the mechanism of the power tillers. More than 14cm, if possible 18cm depth of cut became an important design condition of the tillers. Horsepower of the engine was increased in order to avoid decreasing width of tillage and travel speed.

From 1950 to 1953 National Test was established by the government.[6] A. that time, many manufacturers began to introduce variable models of power tillers newly developed. Then, naturally, farmers were confused in selecting the best machine for his farming system.

Government decided to offer authorized data about the performance of farm machinery to the farmers through the "National Test". Manufacturers were free to participate in the test. However, they challenged well, because, if they passed, they were given the right to indicate "National Test Passed", a special mark that shows the government guarantee for satisfactrory performance of the machines.

In addition to this, loan system from financial agencies to the farmers was permitted easily to the purchase of machine only that passed the National Test. This system forced and encouraged very much the manufacturers to develop better machines.

The wishes to use the power tiller for puddling paddy rice fields created remarkable advancement of many mechanisms. One of them was the advancement of rotary hoes.

Usual type of rotary tillers at that time was equipped with pick tines as shown in **Fig. 3**, which was called "common tine", *futsu-zume* in Japanese.

This tine has tendency to hook easily straws and long weeds on the fields. Thus, a rotary shaft with the tines becomes like a drum of straws and grasses within a short distance travel of tillage, especially in puddling.

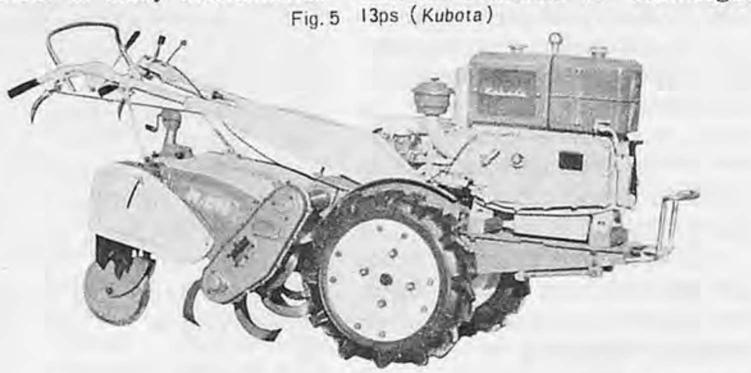
Then, Japanese rotary blades, *nata-zume*, as shown in **Fig.4** appeared in the market to provide prevention of entwining grasses.

Depending on suitable angles, α_n in **Fig. 4** and rotating motion of them, grasses and straws are easy to slip out from the rotary shaft mechanisms along the edge curve of the blade.

Other development of important mechanism was the advancement of sealing mechanisms, wheel structures of specialized iron-lugged wheels and rubber wheels for muddy fields, etc.

Around 1953 to 1955, hand tractors coupled with rotary tillers became available for submerged

Fig. 5 13ps (*Kubota*)



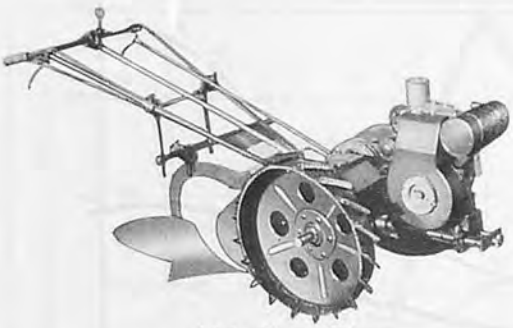


Fig6 Merry Tiller

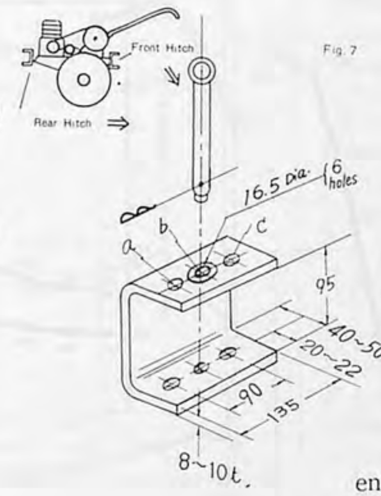
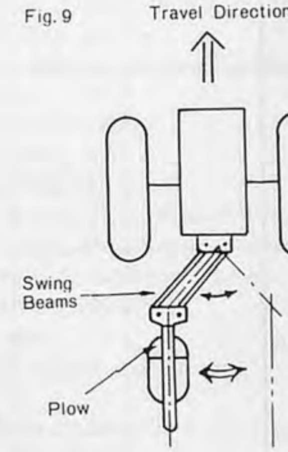


Fig. 9



fields. Possibility to mechanize deeper tillage and also puddling with rotary tillers promoted very much the demands of farmers in Japan.

Bigger horsepower can produce higher tilling performance. So that, the ps of the machine has grown up gradually from about 5 ps to 7 to 14 ps.

These hand tractors with rotary tillers driven by the tractor engine as shown in **Fig.5** were named "Drive Type Power Tiller" in Japan. Bigger horsepower than 14 ps was tried but could not be successful because of handling difficulty caused by too big and heavy weight of the machine.

In 1953, motor tillers of 2.5 ps were imported into Japan from the United States, which name was merry tiller.[7] This tiller had some problems of enough usage for Japanese farmings because of comparatively short life design and simple mechanisms that suit to western condition. (refer to **Fig. 6**)

However, these tillers gave the Japanese engineers good hints of connecting the machines with Japanese farm tools of animal power, such as unique Japanese plows, ridgers, furrowers, rakes, cultivators, small trailers and so forth.

Many types of rotors that should be equipped to drive shafts for wheels were also expected to be used for general rotor tillage and puddling.

Various new attachments developed collaboratively in the attachment manufacturers with power tiller manufacturers.

Important topics for developing mechanisms for this type of power tillers were a hitch mechanism and swinging beams of plows, etc.

Fig. 7 is a standard shape of hitches of Japanese power tillers. The application of this hitch enable them to connect the hand tractor with many attachments. If an attachment is connected by one pin through the center hole b, it can be swung to the left or to the right. If it is connected by two pins through two holes, a and c, it can not be swung.

Fig. 8 & 9 show new plow beam that can swing the plow body, left or right direction, facing it only to the direction of travel, and can be fixed at a position so as to have optimum width of plowing in order to suit with the soil condition.

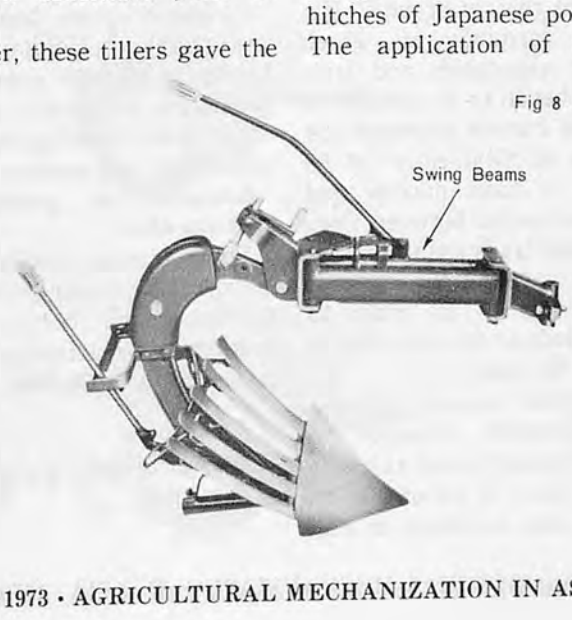
Perfect connection of the hand tractor with adjustable plows and other attachments realized the appearance of professional power tillers that can change the animal power.

Then in 1955, new type power tillers of local brands, equipped with a 2.5 to 4 ps engine, began to be produced from many manufacturers.[8] Good advancement of small gasoline engine of air cooled type assisted their advancement.

This type of machine was ameliorated so as to have effective multipurpose performance for Japanese farming works, including many stationary farm machines such as: threshers, sprayers, pumps, etc. which are driven by power-take-off shafts.

This machine was named "Traction Type Power Tiller", which is sometime called by the Japanese as "Tiller" only. We

Fig 8



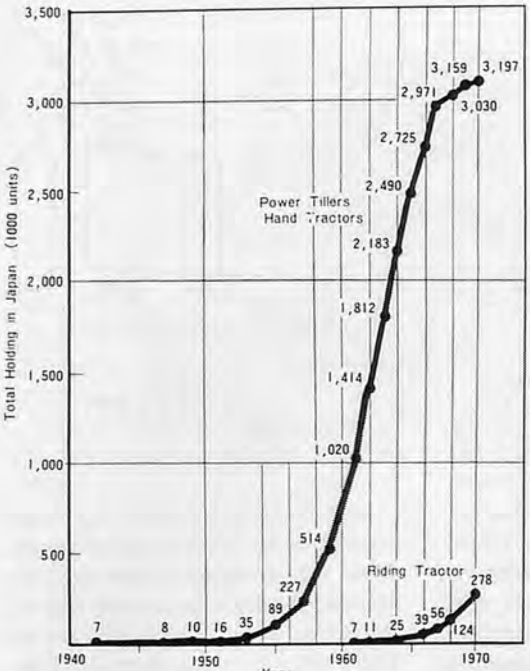


Fig.10 (Source; Statistical data, Ministry of Agriculture and Forestry, Japan)

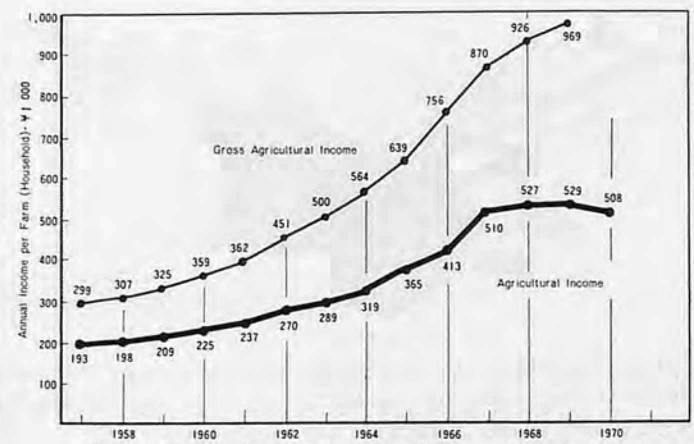


Fig.11 (Source; Statistical data, Ministry of Agriculture and Forestry, Japan)

may say that real mechanized farming in Japan was switched on by this type of machines as shown in **Fig. 10.** (refer to also **Fig. 7)**

At the same time in about 1955 to 1958, many engineers began to try to combine both performance of Drive Type and Traction Type Power Tillers.

Thus, in 1958 to 1960, medium sized "Dual-purpose Type Power Tiller" of 5 to 7 ps was born. This machine can perform a little narrower rotary tillage than that of Drive Type Power Tillers, and also many traction works by changing the rotary tilling device to such attachments as; plows, rakes, trailers, and so forth.

Rotor tillage, like Traction Type Machine mentioned above, is difficult for this type of power tiller because of handling difficulty caused by heavier machine in weight than that of the Traction Type one.

After 1958, big demands from farm area to buy power tillers and hand tractors arisen as shown in **Fig. 10.** Because, the price of such machines for small scale mechanization, that the average size of Japanese farms is about one hectare per farm, was individually about ¥100,000 to ¥300,000 per unit ($278 to $835 in that time)[9], and this was not so great difference from their annual income per farm as shown in **Fig. 11,** and moreover, farmer could select any type (size) of his power tiller or hand tractor and its attachments suiting to his small scale farming system.

Thus, mass production has begun as shown in **Fig. 12**, and Japanese unique mechanized farming was quickly accelerated to progress.

Adding to this, in around 1965, miniature farming of green houses for vegetables and fruit harvesting began to be diffused in Japan. This current provided the appearance of "Mini-tiller" of 1.5 to 2.5 ps to have narrow and shallow cultivation between rows and also light transportation, etc.

Some farmers began to have two power tillers in order to cover all kinds of his farm works throgh out the year.

Now, general concept of maximum production capacity of hand tractors and power tillers in a year in Japan is about 400,000 to 500,000 units as shown in **Fig. 12**, and their total holding is about 3,000,000 units. About 70,000 units were exported in 1970 only.

In the past, many riding tractors were imported as sample machines, and Japanese manufacturers prepared several models after them.

However, the farming and field structure of majority of farms, means paddy rice field, of this island country was too small to have utilization of these big scale machinery without big investment to land reformation and changing structure of farm society, and also a farmer's income was not enough to purchase privately them.

Only Hokkaido area, northen part of Japan, has comparatively wider farms of 4 to 5 ha in average farm size than other area.[9]

Riding tractors began to be used mainly in Hokkaido island.[9] Lately in last 10 years, farmer population is quickly decreasing every year, creating the lack of labor, and the number of farm···household···is gradually decreasing also.

Some farmers began to have co-operative farming, so that, the farmers began to buy gradually small riding tractors of 15 to 25 ps as shown in **Fig. 10.**

B. Classification Concept of Japanese Power Tillers

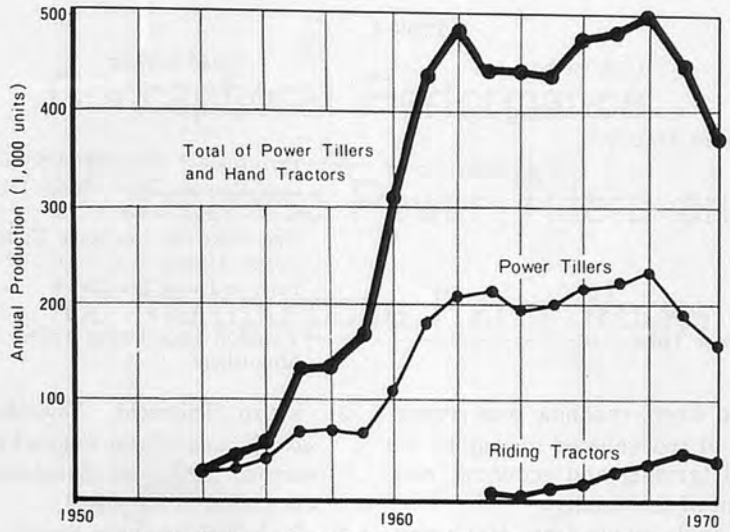


Fig.12 (Source; Statistical data, Ministry of Agriculture and Forestry,Japan)

1. Modern Classification

In Japan, power tillers mean the garden tractor of walking type, such machine with tilling equipment and motor tillers.

There are many ways of classification methods depending on the sort of engines mounted on them, their horsepower, type of main tilling devices etc.

The common way of classification of Japanese Society of Agricultural Machinery is as follows:

1 . Drive Type Power Tiller, (7 to 14 ps)

Detailed structure is classified as follows:

* large size
* sort of main tilling device mounted
* width of maximum tillage
* sort of engine, ps, cooling system, etc.
* shift gear system
* frame structure

(refer to Fig. 5)

2 . Dual-Purpose Type Power Tiller, (5 to 7 ps)

Detailed structure is classified as follows:

* medium size
* sort of main tilling device
* maximum tilling width of the main tilling device
* sort of engine, ps cooling system, etc.
* shift gear system
* frame structure

(refer to **Fig. 13**)

3 . Traction Type Power Tiller (Tiller), (3 to 5 ps)

Detailed structure is classified as follows:

* small size
* sort of engine, ps, cooling system, etc.
* shift gear system

(refer to **Fig. 14**)

4 . Mini-tiller, (less than 3 ps)

Detailed structure is classified as follows:

* very small size
* sort of engine, ps, etc.
* shift gear system

(refer to **Fig. 15**)

2. Classification Differences of Power Tillers between USA and Japan

Classification of power tillers are shown **Table 1.**

In the United States of America, Garden Tractors are not the tractors used for professional farming nowadays. Such tractors are called "Farm Use Tractor", and separated clearly from Garden Tractors.

Garden Tractors (in America)

Fig. 13 6.5ps (*Kubota*)

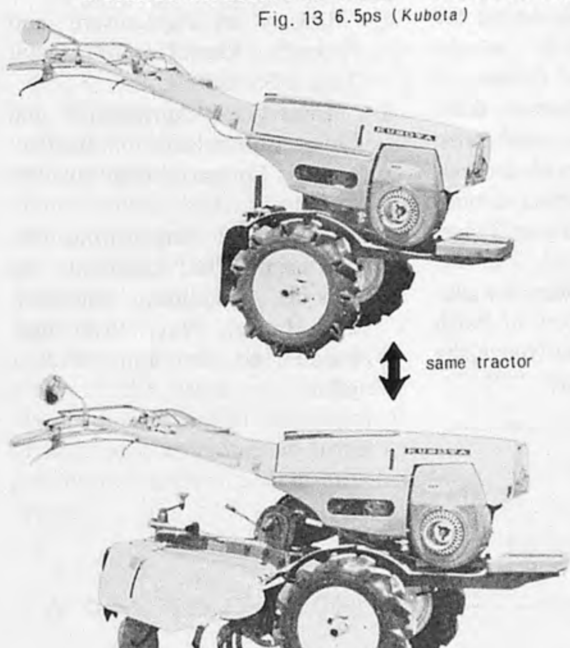


Fig. 14 4.5ps (*Mitsubishi*)

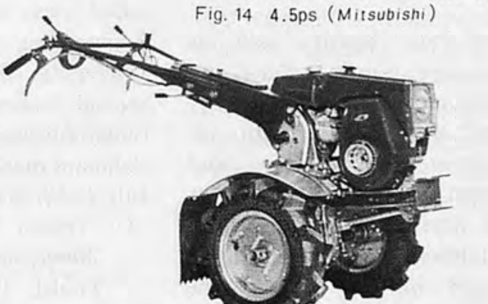


Fig. 15 2.5ps (*Kubota*)

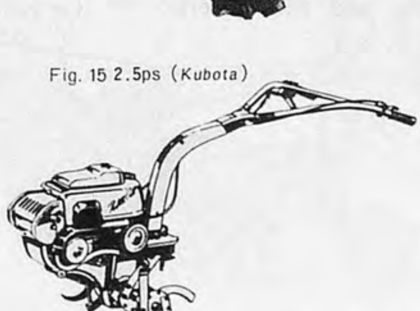


Table 1

USA method		Japan method
Garden Tractor	Riding type	Riding tractor
	Walking type	Performance looks like the Dual-Purpose Type Power Tillers. Size looks like the Drive Type Power Tillers. Form is Hand Tractor
Motor Tiller		Traction Type Power Tillers and Mini-tillers

are defined as tractors weighing less than 1200 pounds (basic machine), typically powered by air-cooled engines with fewer than four cylinders and total piston displacement of under 45 cubic inches…by "Current Industrial Reports" of the US Department of Commerce.

Motor Tillers are power tillers which are comparatively smaller in size than the walking type garden tractor, and are able to till lands with Rotors attached to drive shafts, instead of wheels.

The above mentioned garden tractors and motor tillers are used mainly for domestic purpose such as gardening, because the sizes of farms in the United States are so big that such machines are to small and uneconomical to be used for professional farming in the United States.

Every Parts of Japanese power tillers are so designed to be used professionally for at least 5 to 7 years at a driving hours of about 250 hours per year.

Some kinds of western power tillers are also designed so as to be professionally used machine of long service life.

Conclusion

At any rate, history tells us that Japanese power tillers and hand tractors are obtaining many ideas and knowledges from advanced western countries, and had grown up to the present Japanese nation. However, there was collaborative efforts among the people in the farms, the manufacturers and the government. Every machine was remaked and redeveloped to suit to the local farming and economic condition of the country.

It took about forty (40) years, from 1920 to 1958, to develop all necessary models. Real diffusion of farm mechanization in Japan began to grow rapidly in 1955 to 1958, when every kind of farm work could possibly be done by machines instead of animal power. These Japanese machines have so many different characteristics from western machines, that made their classification also different.

■ ■

References and Footnotes

The original of this paper was prepared for the lectures during the second semester, 1969-70, to the upper class men of the College of Engineering, Central Luzon State University, Philippines, and also special lecture in Ibaraki International Agricultural Training Center, Uchihara-machi, Ibaraki-ken, Japan, July 12-13, 1972.

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2) Ryuzo Takeuchi, *Noyo-Hatsudoki-Kogaku* (Farm Engine Engineering), 1963 Sept. Sanei-shobo Co. Ltd., Tokyo, p39-40.
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4) Original Utiliter is also kept in the author's laboratory room, Department of Agricultural Machinery, Mie University, Japan.
5) Calculated from, Ministry of Agriculture and Forestry, Agriculture and Forestry Statistics, 1951 to 1953.
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Conceptional Performance of Japanese Power Tillers and Hand Tractors for Multipurpose Farm Works

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Preface

Japanese Power Tillers and Hand Tractors have individual characteristics for working performance depending mainly upon the size of machines.

The classification of machines is :

Large -- Drive Type Power Tiller
Medium -- Dual-Purpose Power Tiller
Small -- Traction Type Power Tiller
Very Small -- Mini-tiller

In this print, each model will be introduced as to its conceptional characteristics, specifications, performances, etc, which are summarized from many machines' catalogues, books, and reports.

Author expects the readers to refer to the other report herein, about the historical development of Japanese machines in order to get better understanding of this report.

A. Drive Type Power Tiller

1. Characteristic Concept

Typical form of this machine type is shown in **Fig. 1.** This machine has the strongest tilling performance among power tillers. However, this has fewer utilities for multipurpose farm works than other types, and it belongs to the large size power tiller group.

2. Specification Concept

* Engine horsepower is about 8 to 14 ps at maximum crankshaft output. Most engines are water-cooled Diesel engines of horizontal one cylinder and four cycles.
* A main tilling device is coupled directly to the tractor with bolts and nuts, and driven by the engine mounted on the tractor.
* Width of tillage is about 55 to 75 cm, and maximum depth of cut is about 15 to 18 cm.
* The gross weight of a machine including a standard engine, a tilling device and two rubber wheels is about 300 to 450 kg.
* Main dimensions are about:
  - Overall length……2200 to 2500 mm
  - Overall width …… 750 to 1000 mm
  - Overall height……1000 to 1200 mm

3. Performance concept

Although the performance of the machine is changeable under many conditions, normal one of preparatory tillage with common width and depth is about 50 to 90 minutes per 10 areas, which means that these machines are able to perform more than 5 to 7

Fig. 1

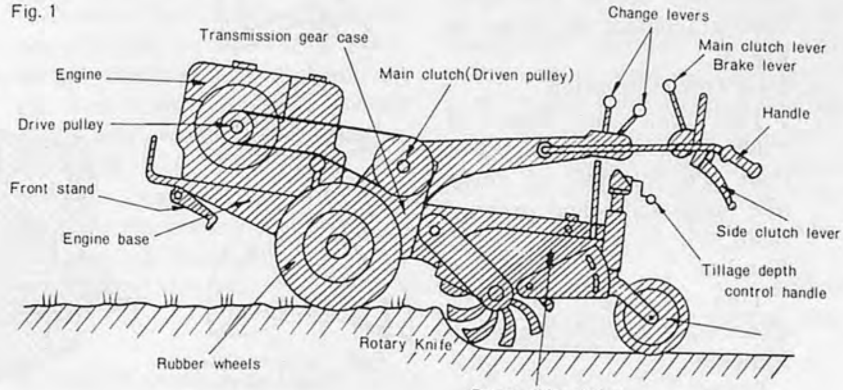


Fig. 2

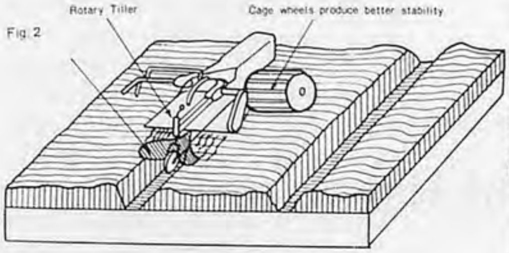


Fig.3 Pudlling

Fig.5 Pumping

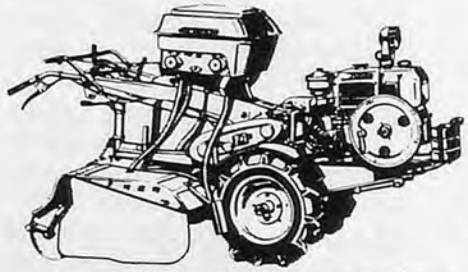


Fig.4 Fertilizing Seeder (source; Catalogue of Manufacturer)

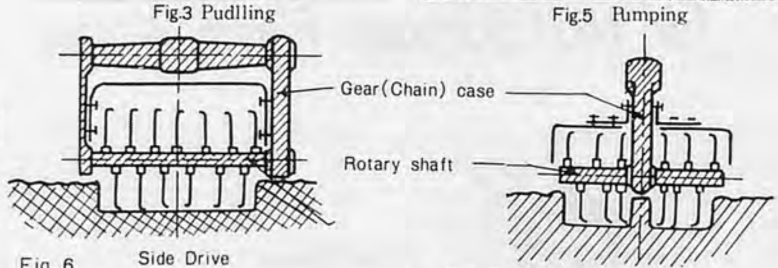


Fig. 6 Side Drive

Fig. 7 Center Drive

times quicker than an animal as water buffalos.

Main works are:

a. Preparatory tillage before planting

Plowing and harrowing are both done at a time through one passing with a standard tilling device such as a rotary tiller.

Ridging is done by attaching a ridger, as shown in **Fig. 2.**

Puddling is done with the standard tilling device. Sometimes, standard rubber tires are changed to cage wheels to get better stability. A rake or leveling plate can be attached behind the tiller as shown in **Fig. 3.** In the grassy field, special drum rotary is effective.

b. Seeding and fertilizing

This is done by mounting a specialized seeder and fertilizer-attachment as shown in **Fig. 4.**

c. Inter-row cultivation

This can be done, if machine width is narrower than the interval of rows, like sugar cane and orchard fields, etc.

d. Trailing

This is rarely done by attaching a suitable trailer.

e. Mowing

Rotary mower can be attached to the front of the machine.

f. and others

Power source to many works such as; pumping, threshing and so forth, as shown in **Fig. 5.**

* Designed ranges of traveling speeds for different farming activities are as follows:

0.25 to 0.4 meters/second: for seeding and fertilizing, reverse, ridging.

0.3 to 0.7 meters/second: for tillage with the standard tilling device.

0.5 to 0.8 meters/second: for inter-row cultivation.

0.5 to 1.2 meters/second: for puddling, harrowing, (plowing)

5 to 25 km/hr: for trailing

The above mentioned speed ranges are arranged into their shift gear systems. These ranges are also applied by other type power Tillers.

4. Types of main tilling devices

* One of the most popular tilling devices is "Rotary Tiller" which is called only "Rotary" in Japan. This machine has a horizontal rotary shaft with 16 to 22 rotary

Fig.8 (source; Catalogue of Manufacturer)

Fig. 9

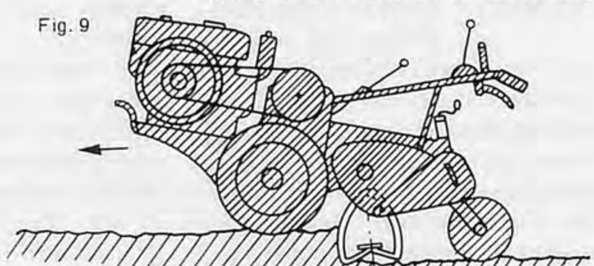


Fig. 10 YAMASA (1953)

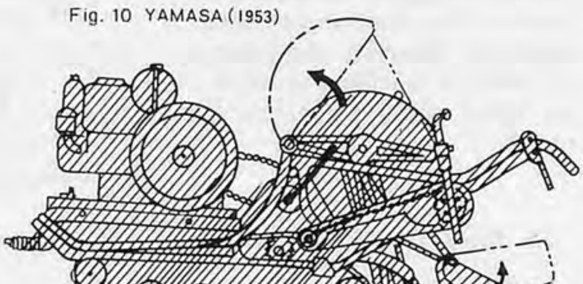


Fig. 11

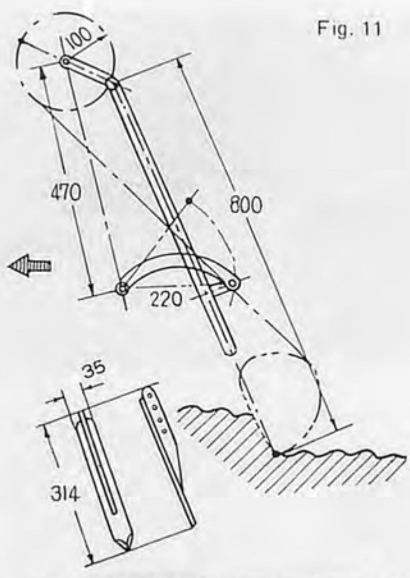
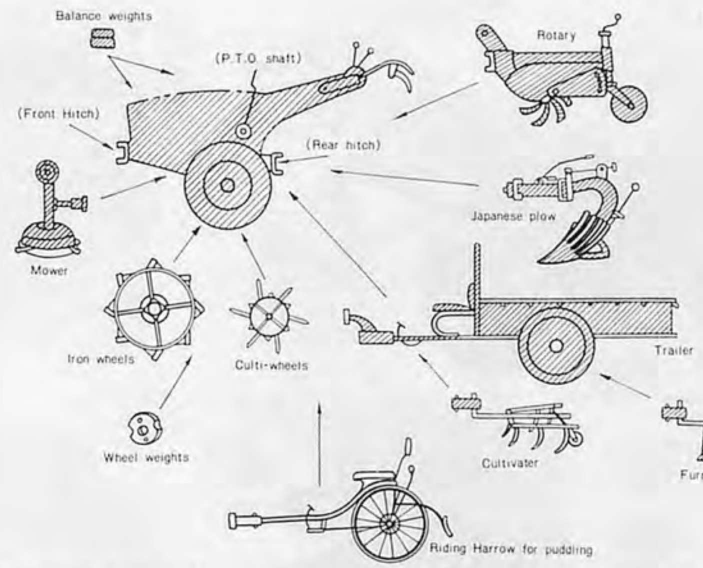


Fig.11 Yamasa Co. (source; Report of National Test, Ministry of Agriculture and Forestry)

Fig. 12



tines or knives on it, rotating about 130 to 400 rpm. (refer to **Fig. 1**)

There are two types of transmission systems as shown in **Fig. 6** and **7.** One is "Side Drive Type" where power is transmitted from one side of the rotary shaft, while the other is "Center Drive Type" where power is transmitted from the center of the rotary shaft.

Center drive type is more convenient to adjust the tilling width than side drive type, but this type is apt to leave some untilled portion under the center-reduction-case of the device, especially in case of wet and sticky field.

In such case, this rotary tiller is equipped with additional tools like a coulter or special rotary knives to cut off soil under the case.

* There are only a few but interesting types.

Fig. 8 and 9 is a "Screw Type Power Tiller" which has an even-numbered vertical rotary shafts. As a rule, two shafts should rotate at opposite directions, of which the upper shank portion of each shaft is supported. To the shaft, Screw Blades are fixed as shown in the figure.

Tilling performance is about the same as that of rotary tiller mentioned above. However, these screw blades have screwing action, in other words, sinking down action into the soil. (Rotary tiller has floating up force.) So that, vertical stability of the machine is better than rotary power tiller.

Altiough this type of power tiller was discontinued in Japan, several screw cultivators with same kinds of principles are existing as special attachments of riding tractors in western countries.

* One of discontinued but interesting models is "Crank Type" as shown in **Fig. 10** and **Fig. 11.**

This has complicated heavy mechanism but with high tillage efficiency because of the rough harrowing effect to the soil and smaller frictional method of the tine to soil.

So that, 1.5 to 2 times wider cultivation than another type tillers of same horsepower is possible for this model. And moreover, the tine can not be entwined about with weeds and straws on the fields.

These machines showed nice tilling performance in unirrigated paddy fields covered with many grasses and straws.

B. Dual-Purpose Type Power Tiller

1. Characteristic Concept

The shape of this machine is a little smaller in size than Drive Type one. This has various forms. Typical relation of this machine with important attachments is shown in **Fig. 12.**

This is medium size power tillers between "Drive type one" and "Traction type one" mentioned hereafter.

A little bit smaller tilling device and attachments than that of Drive type power tillers, such as "Rotary" or "ridger" etc, are able to be attached to the tractors, and also, by taking it off, plow or other attachments are able to be attached or mounted in order to do many works. So that, these machines have smaller horsepower but higher utilities than that of Drive type one.

2. Specification Concept

Engine horsepower is about 5 to 7 ps (maximum horsepower as crankshaft output). There are many engine types as follows:

@ water-cooled Diesel engines of horizontal one-cylinder.
@ air-cooled gasoline engines of vertical one- or two-cylinder, or inclined one-cylinder.
@ water-cooled kerosene engines of horizontal one-cylinder.
@ and few others.

Most are four-cycle engines.

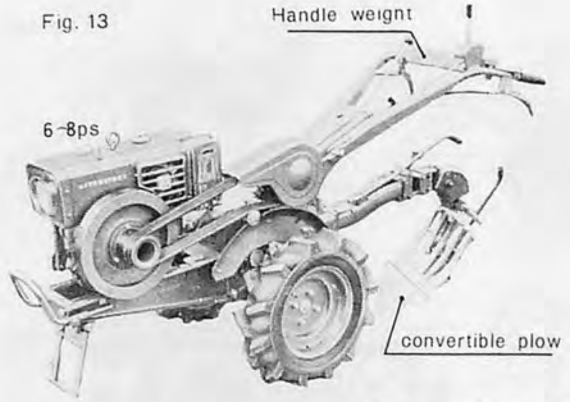


Fig14

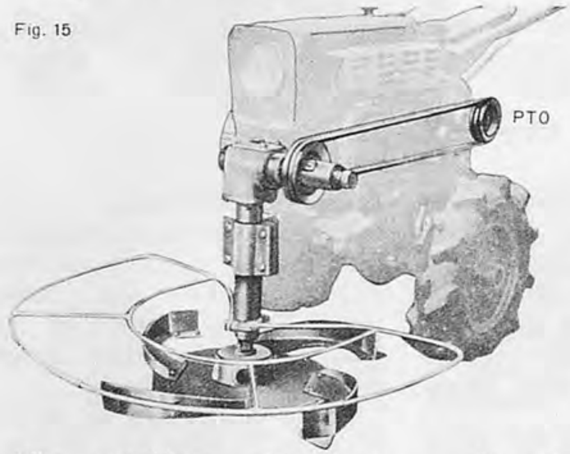


Fig.16 Pipe-Frame trailer with a 6.6ps hand tractor (source; *Trade and Industry of Japan,* JETRO, 1968, p. 128)

The machines which are mounted with air-cooled engine are easier to handle than those machines which are mounted with water-cooled engine, because of lightness like traction type power tiller.

However, the machine with water-cooled engine has better tillage stability like Drive type one because of heavier weight than the machine with air-cooled engine.

* Width of tillage with main tilling devices of rotary or screw-type is about 450 to 600 mm, and the maximum depth of tillage is about 15 to 18 cm.

* The gross weight of a machine equipped with a standard engine and rubber wheels, except any other attachment, is about 120 to 200 kg. The weight of a main tilling device with standard knives is about 70 to 100 kg.

* Main dimensions are about:

Overall length······1800 to 2150 mm.

Overall width ······ 650 to 750 mm.

Overall height······1000 to 1200 mm.

3. Performance Concept

* Although performance is variable under many conditions, general concept of performance concerned with normal tillage is as follows:

@ tillage with a main tilling device such as a "Rotary" is 60 to 120 minutes or about 1.5 hours/10 ares.

@ tillage with a standard Japanese plow is 50 to 90 minutes or about a little more than 1 hour/10 ares.

This means that the machines can perform more than 5 to 6 times quicker than an animal such as a buffalo.

* Main works are:

a. Preparatory tillage before planting

Plowing is done by attaching a "Japanese single plow" or "Japanese plow with a jointer". **Fig. 13** shows a example.

Plowing and harrowing are both done at a time through one passing with a standard tilling device such as a rotary.

Ridging is done by attaching a ridger same as the case of Drive Type machine.

Puddling could be done in so many ways of traction type and drive type. As shown in **Fig. 14,** a Riding Harrow is adaptable to have puddling. This is used with Puddling Rotors as a rule.

b. Seeding and fertilizing

This is done by mounting or attaching a specialized machine.

c. Inter-row-cultivation (weed and disease control)

This is done by attaching a cultivator or weeder, if row clearance is set so as to fit the machine.

d. Furrowing

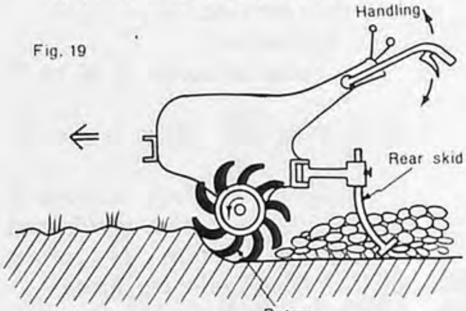
This is done by attaching a furrower, or cultivator with a furrower.

e. P.T.O. work

@ mowing—done by attaching a rotary mower to

Fig.17 (source; Catalogue of Manufacturer)

Fig. 19



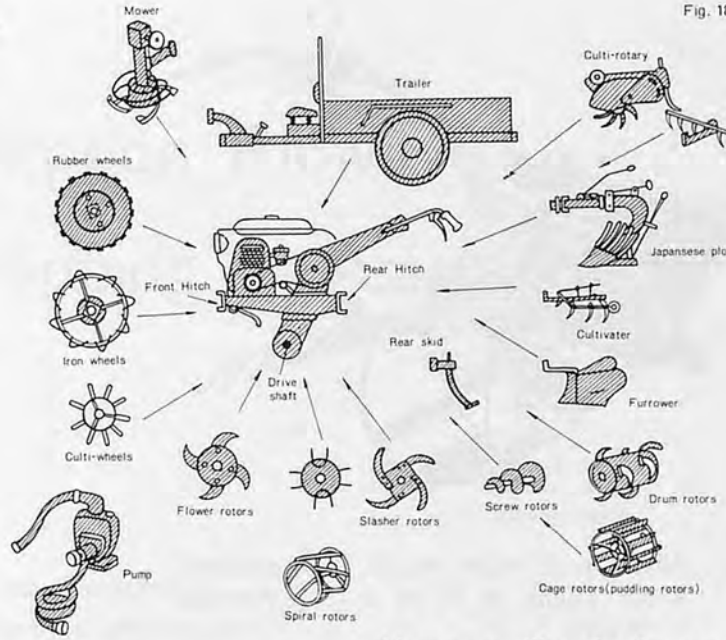


Fig. 18

the front as shown in **Fig. 15.**

@ pumping—done by mounting a suitable pump on the rear hitch or through PTO shafts to a stationary pump.

@ spraying—same as above.

f. Trailing

This is done by attaching a trailer as shown in **Fig. 16.** Special trailers of which wheels are drived by p.t.o. shaft are useful for powerful transportation in hilly districts.

g. and others

Public and construction works with truck layer device as shown in **Fig. 17.** Many stationary works using p.t.o. shaft etc.

* The most popular tilling device is "Rotary Tiller" of centerdrive type which has 12 to 18 tines or knives rotating about 130 to 400 rpm.

* General concept of travel speeds is the same as the drive type power tiller mentioned above. Most machines have both main and sub-shift gear systems of 6 to 8 forward and 1 or 2 reverse gears, in order to perform many kinds of farm works.

C. Traction Type Power Tiller

1. Characteristic Concept.

* The machine is connected with many attachments as shown in **Fig. 18.**

* Comparatively a smaller power tiller in size than the dualpurpose type power tillers. However, this machine has best performance in multipurpose farm works.

* This machine is able to perform "Rotor Tillage" with many kinds of "Rotors" attached to the Drive-shafts instead of Drive wheels, and with a "Rear Skid" attached to a "Rear Hitch Box", as shown in **Fig. 19.** Width of cut is adjusted by the number of rotors.

So that, more kinds of farm works done by animal powers can be performed by this machine. This machines are the most diffusive in Japan. Annual production of these is about a half of total production number of all Power Tillers and Hand Tractors in Japan.

2. Specification Concept

* Engine horsepower is about 3 to 5 ps. Common type of mounted engine is forced-air-cooled one-cylinder gasoline engine.

* The standard tilling device of this power tillers in the western countries, in general, is "Rotors" mentioned above. But, in Japan, the standard one is "Japanese plow".

* Normal plowing width of a standard Japanese plow with a jointer is about 18 to 24 cm, and the depth of cut is about 15 to 18 cm.

* The weight of a machine without such attachments and wheels is about 100 to 120 kg. Average weight of rubber wheels including both left and right extension wheel shaft is about 20 kg.

* Main dimensions of the machine with standard rubber wheels, except any other attachment are about:

Overall length······1550 to 1900 mm
Overall width ······630 to 700 mm
Overall height······920 to 1200 mm, adjustable by handles.

3. Performance Concept

* Although performance is variable under many conditions, general concept of performance concerned with normal tillage is as follows:

@ tillage with a standard Japanese plow: Plowing is 1.5 to 2 hr./10 ares.

Fig. 20

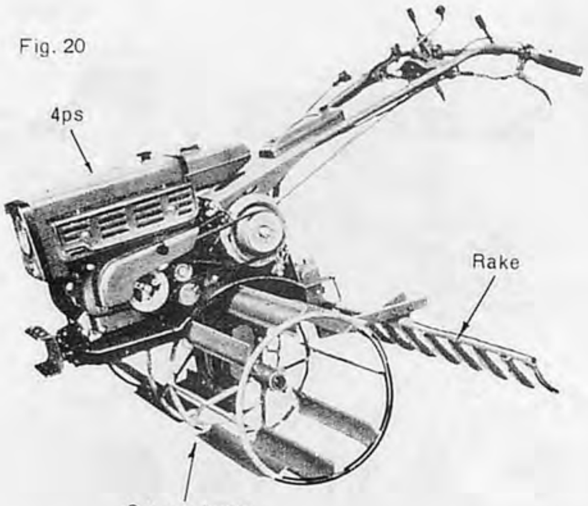
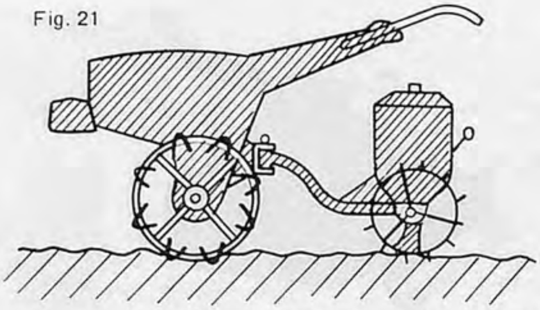


Fig. 21



@ tillage with main rotors: Rotor Tilling is 1.5 to 2 hr/10 ares.

These mean that this type of machines are not able to perform perfect Rotary-tillage like bigger tractors, but are able to do Rotor-tillage. Ability of plowing is about 4 to 5 times quicker than an animal such as a buffalo.

* Main works are:

a. Preparatory tillage before planting

Plowing is done by attaching a Japanese plow.

Rotor Tillage: plowing and harrowing are done at a time through one passing. Travel speed is about 10 cm/sec.

Ridging is done by attaching a furrower. One ridging has to be finished after 2 to 3 passing of furrower.

Puddling is done by rotor tillage with a rake, instead of a rear skid as shown in **Fig. 20.**

b. Seeding and fertilizing

This is done by drafting or mounting a specialized seeder or fertilizer-attachment as shown in **Fig. 21.**

c. Inter-row-cultivation

This is done by attaching a cultivator, culti-rotary, many kinds of rotors, and special weeder for rice paddy fields.

d. Furrowing

This is done by attaching a furrower. One side hiller is available.

e. Weeding

This is done by attaching special rotors for scraping and general rotors for blinded weeding.

f. P.T.O. work:

Mowing is done by attaching a rotary mower to the front of the machine.

Pumping is done by mounting a water pump on the rear (or front) hitch, or by fixing both machines on the ground.

Spraying ... same as above.

g. Trailing

This is done by attaching a trailer. In hilly districts, front and rear carriers of cage type are hitched on the front and rear side of the machine, and handled easily and safely by a walking man.

h. and others: PTO shaft works and transportation.

4. Utilization of Rotor Tillage

a. Principle of Rotor Tillage

As shown in **Fig. 19,** rotating rotors dig down into the soil. The rotating motion of rotors produces support to the pressing down force R_1 of the machine and Driving-forward-force P_1, that these forces R_1P_1 are the component forces of total tillage resistances. Then, driving-forward-force P_1 is opposed and supported by the scratching resistance of the soil to the rear skid.

b. Application

Speed of rotors is 50 to 70 rpm.

Depth of tillage is usually 10 to 15 cm.

Width of tillage is about 30 to 100 cm, which is adjusted by the number of rotors, installed to the machine.

It produces big handle irregular motion because of big pitching, rolling and yawing of the machine.

So that, the driver of rotor tillage is easier to be tired than common plowing done with plows. However, it is convenient to till narrow space because of very slow forward speed.

This characteristics are as useful as general cultivators for inter-row-cultivation. Many kinds of rotors and rear skids are prepared for variable field, soil and plant conditions.

D. Mini-tiller

* This is a very small and handy power tiller with an engine of 1.5 to 2 ps rating.

* Its main works are narrow and shallow cultivation of weeding, harrowing and furrowing between rows, and light transportation with a seat-car or carrier.

■ ■

Important Role of Reversible Nippon Plows for Multiple Cropping in Asia

Atsushi Matsuyama
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I. Why was the Plowing operation swiftly changed from animal power to small power tillers?

In 1952, a Merry Tiller (a small power tiller with 2.5 Hp gasoline engine) was imported into Japan. This Merry Tiller had no wheels but tines attached to the axle which cultivated field breaking the soil. (see **photo No. 1**). After a while, they attached two wheels to the axle instead of the tines to utilize the drawing force for plowing, cultivation, trailer workor another purpose. They called it as 'Handtractor'. (see **photo No. 2**)

Though there was no difficulty to draw a cultivator, the small hand tractor with 2.5 Hp engine could not fully draw the reversible Nippon-plow with the plow body (share and mold board) which was used for animal plowing because of the big resistance.

So, we invented a special plow which could automatically decrease the width of plowing. (see Japanese patent, No. 468093). That function is described as follows.

In the case a farmer wants to turn the soil to his right side during going of plowing, if he turns the reversible handle (see **plate I**) to right side, the top of the beam which is at the same drawing point moves a little toward left and the width of plowing becames automatically narrow.

In the case of return plowing which needs to turn the soil left side, if he turns the reversible handle turn left, the plowing width becomes automatically narrow because the top of the beam moves a little toward right.

With this effect, the small power tiller of 2.5 Hp completely succeeded to do the plowing work much better than a powerful animal. Comparing the high

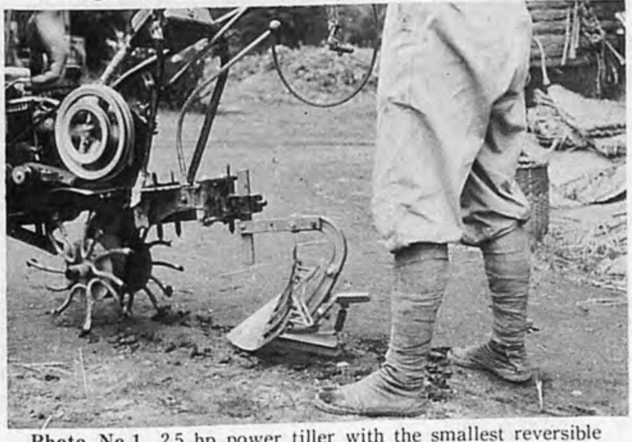

Photo No.1 2.5 hp power tiller with the smallest reversible Nippon plow. See the simple and practical design of the tiller and the plow.

Photo No.2 Spring season cultivation in paddy field by 3 hp power tiller with a reversible Nippon plow.

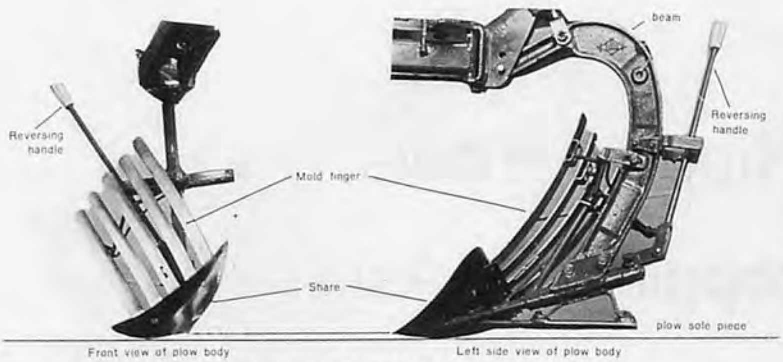

Plate I Reversible Nippon-Plow for Hand Tractor

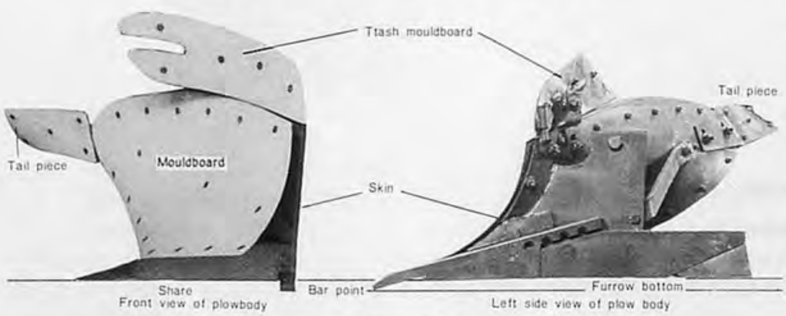

Plate II Bottom Plow with Plastic Moldboard for Wheel Tractor

Photo No.3 Inter cultivation for the maize field by the above power tiller with the plow.

price of the big power tiller with a direct drivened rotary attachment which had been developed since 1930, the price of the small power tiller with the improved reversible Nippon plow was enough cheap for most of farmers to buy it with the money which was got by selling one cow. It was about ¥150,000. At the same time it was easily manufactured by simple factories. These power tillers utilizing drawing force could also used in may ways with various attachment. (see **photo No. 2, No. 3, No.4, No. 5,)**

With these reasons, this kind of power tillers swiftly started to spread into Japanese farming replacing animals.

After that invention, the Wide-regulating mechanism (see **plate** III) was invented, which made it easier to adjust the width of plowing in various degrees with the principle of a parallelogram. As this plow was so convenient for plowing operation, this accelerated the tendency of replacing animal farming with small power tillers with reversible Nippon plows.

As gradually hand tractors with higher power became to be manufactured, suitable plows with bigger capacity also became to be used widely. (see **photo No. 5, No. 6, No. 7, No. 8,)**

II. The History of the reversible Nippon-plow and the excellent technical points.

This reversible Nippon-plow helped greatly agricultural mechanization in Japan described as above. Not only in Japan, this would be welcomed in every place of the world. The simply history and the reason are as follows.

(1) The reversible Nippon-plow was originally developed from the old Chinese plow. It was at first invented as a reversible plow for animal drawing by Mr. Genzo Matsuyama (1875-1963, who is the father of the author) in 1900 (Japanese patent No. 4975). It contributed much for promoting animal farming. (In Japan almost farmers did not use

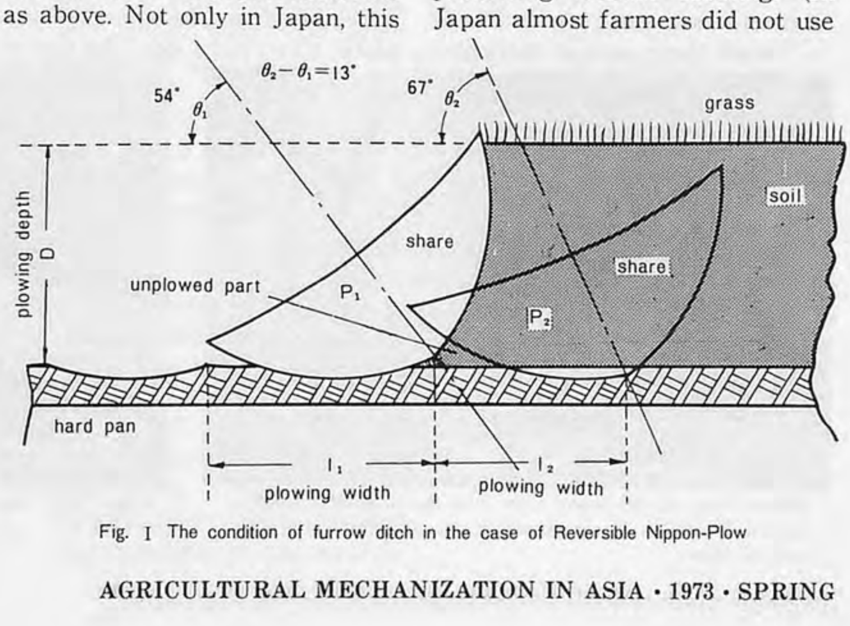

Fig. I The condition of furrow ditch in the case of Reversible Nippon-Plow

Photo No.4 Plowing in the paddy field.

Photo No.6 Backside view of the previous photo. This power tiller is about 6 hp.

animal power for their agriculture for long time. Only 20 years ago, Japanese government was doing the extension work for teaching how to use the animals.)

(2) This reversible Nippon plow is not an old soil-opening type but an soil turning type, which can be used in the common field, paddy field and even in the extremely wet field. This is quite a convenient plow for all round use.

(3) Comparing usual bottom plows (see **plate** II, **Fig** II), the specific resistance of soil is much less in the reversible Nippon plow. This assures that a tractor can draw a Nippon plow with small wheel slip even in the case the cut way area of the furrow slice turned by the Nippon plow is larger than that with the bottom plow at the same depth of plowing in the same field. This is widly proved by farmers and researchers. This is also easily found in the comparison of the fuel consumption of a tractor.

(4) Nippon plows have higher stability against the rolling and pitching of a tractor. The reasons are as follows. *Rolling of tractor, which is naturally caused by the unevenness of field surface.* See **plate 1, plate** II, Fig I, and **Fig** II.

In the case of the plowing by a reversible Nippon plow, the condition of the furrow ditch is shown in **Fig** I. Supposing that

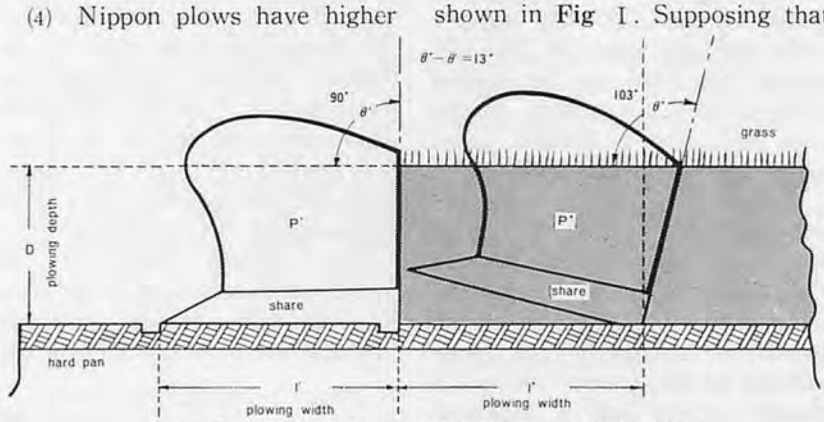

Fig. II The condition of furrow ditch in the case of Bottom Plow

Photo No.5 Plowing after harvesting cabbages. Good stability shows no drivers.

Photo No.7 Reversible Nippon-plow (twin)

Photo No.8 Plowing in common field by 15 hp four wheel tractor

the 54 degree of θ_1 (the degree of inclination of the share P_1 (**Fig** I, **plate** I)) would be changed to the 67 degree of θ_2 (the degree of inclination of the share P_2 (**Fig** I)) by the rolling of a tractor, the mean depth of the hard pan would be kept constant and the unplowed part would be took off, though the hard pan be shaped with a little unevenness. In the case of using a bottom plow, please see **Fig** II and **plate** II.

P′shows the original stabilized condition of a bottom plow with $\theta = 90°$. P″ shows the condition of the change of the degree of the inclination of the share which would be caused by the same amount of the tractor rolling. It results a great deal of unplowed part under the share as shown in the **Fig** II.

The pitching of a tractor and the plowing: Comparing the plow sole piece of the Nippon plow (**plate** I) and the furrow bottom of the bottom plow (**plate** II), the former is always shorter. It means that the sensitivity for the change of the plowing depth during the plowing is much less in the Nippon plow, and that it can do more even plowing operation than the bottom plows.

(5) The effective Wide-regulating Mechanism (**plate** III)

The ratio of the depth of plowing and the width of plowing can be easily adjusted by the Wide-regulating Mechanism in the case of Nippon-plows. This is the one of the greatest advantage of a Nippon plow. Even using a tractor with small power, deep plowing can be achieved by decreasing the width of plowing with the wide-regulating mechanism. In the case we need to do much deeper plowing, the reversible Nippon plow with jointer (**plate** III) can be used.

In the case of a bottom plow, the ratio of the depth of plowing (D) and the width of plowing (1′) is always almost fixed as shown in the **Fig** II and **plate** II of the plow body.

In the case of a Nippon plow (**Fig** 1), though the general condition is $D > 1_1, 1_2$, it can be freely adjusted like $D \leqq 1_1, 1_2$ when it is needed.

In the case of the bottom plow (**Fig** II), the ratio is always $D < 1'$. Even when they want to do deeper plowing adjusting the ratio as $D \geqq 1'$ as the tractor can have still spare power, the plowing resullts very usteady operation and bad turning action. This is the defect of a bottom plow.

The Nippon plow can do steady operation even in the case of difficult deeper plowing, because the turning action of the Nippon plow can turn the furrow slice throwing out them side-way after bringing upwards them without doing impossible twist turning in the case of the bottom plow.

III. The importance of the research and development work of plows for small power tillers used in the developing countries.

Amount of export of our reversible Nippon plows to Asian countries, European countries and other part of the world are increasing with small hand tractors.

In Asian developing countries urgently need to prepare the situation for producing more food coping with the rapidly increasing population. How can we do it? Most of farmers are small scale farmer with the holdings less than three ha. Agricultural level is limited. There are enough solar energy in these countries. These condition means that it is essential for them to increase land productivity with introducing of multiple cropping and needed mechanization, which will create new style of agriculture, chance of new employment and new foods.

The mechanization system with small power tillers with revers-

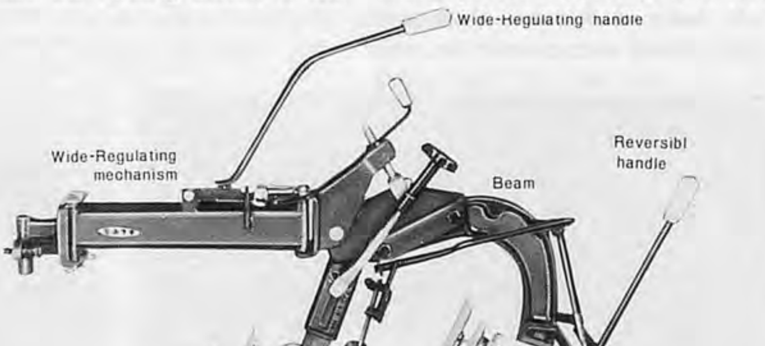

Plate III Reversible Nippon-Plow with Jointer for Hand Tractor ible plows and other various attachment would be essential for these purpose.

Important implementations for Asian farmers are :

(2) Selection of a suitable Multiple cropping pattern to make his income maximum.
(2) Suitable guidance for the cropping techniques.
(3) Suitable irrigation.
(4) Economical mechanization system for overcoming the peak labor.
(5) Small power tillers which has the natures of the multipurpose, enough to cheap for a individual or 2-3 farmers to buy, easy to manufacture locally.
(6) Research and development of the system of implements for the small power tiller which can fully cover the complicated multiple cropping operation.

In every country, economical soil cultivation is done by plowing. Though people in Asian countries imagine the power tillers with rotary attachments when they say on a 'power tiller', these rotary type power tiller are generally more expensive, more difficult to repair, needed more expensive facilities for manufacturing, more heavy to operate comparing with the power tiller with drawing equipments. Of course they have several good points. Though the heavy rotary type power tiller was first developed in 1930, it took very long time to be introduced in individual farmer, even in Japan. The most of the 3.2 million powertillers on Japanese farms are these with the engine less than 5 Hp and reversible Japanese type plows and other drawing equipment. Power tillers at present design can also use rotary attachment.

We can say that the present mechanization system with rotary type power tillers in Asian developing countries needs much money. This was caused by the simple reason that there is still no research and development activities reversible Japanese type plows to be adapted for the soil conditions in these countries. Without these research and design work, swift introducing of multiple cropping method with suitable power tillers could not be realized. In may times I have heard that people in developing countries said "We can plow our fields by animals, but small power tillers less than 5 Hp cannot plow our field of hárd soil". This is wrong observation forgetting any effort of improving plows. The small power tiller of 3 Hp can always plow the field with a improved reversible Nippon plow, if the same field can be plowed by a pair of cows.

The research on plows for small power tillers is one of the key points to promote agricultural mechanization in Asian developing countries.

As to the power tiller itself, they don't need any kind of such gorgeous power tillers as Japanese made. They really need redesigned simple power tillers which are easy to operate, enough cheap to buy, easy to locally manufactured and easy to repair.

As to production of such reversible Japanese type plows after suitable design, it is easy for manufacturers in the developing countries to produce them locally only importing special steel parts like a plow share.

As to plows for medium or large four wheel tractors, discplows are welcomed in southeast Asia and Oceania rather than bottom plows. Redesign of reversible Nippon plow suitable for each soil conditions is also needed for our wheel tractors.

Although we have to promote the tractorization, we absolutely need to improve animal drawn equipments, because most of their farming jobs are done by animal power at present, and also there are still many places where any kind of tractors cannot be used. Especially improved reversible Nippon plows are needed to improve the efficiency of animal use.

We have just started the project to replace the present casted plow share by special steel share which has sharpness and long-life. We have asked for researchers in the agricultural experimental stations in Ceylon and Thailand to test the special steel share. This share is the same one used for reversible Nippon plows with power tillers, which shows successful results. For animal use, we are now exporting reversible Nippon plows redesigned to be easily produced in the developing countries. We recommend to import only steel parts and to produce the other parts locally.

Improvement of plows, power tillers and related attachments is essential for developing agriculture and agricultural machinery industry in the developing countries just as same as in Japan.

I sincerely hope that many engineers will start these design work as soon as possible in the developing countries. ■ ■

(Continued from p.117)

a few tillers are produced. An irrigation at the crown root initiation stage stimulates root development and tillering in wheat. Tiller initiation, preflowering, flowering and grain development are normally critical stages in crop growth. When there is shortage of water, it is better to take care first of the critical stages to obtain increased water use efficiency.

■ ■

New Co-Operating Editors


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A Continuous Rice Production System

First prototype of a portable thresher developed at CIAT during 1972. Two men cut, thresh, clean, and bag 480 to 600 kgs per a day.

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The most productive lands in Tropical Asia are located in the naturally flooded, poorly drained lowlands used for rice production. These same areas are among the least productive areas of tropical America as they are in swamps and dry season pastures. CIAT is in a unique position to develop a production system suited to these tropical America lowlands by blending of the most adapted Asian wet land practices and Western industrial scheduling. As a first step continous production has been implemented during 1972 on the CIAT fields and will be extended to other tropical lowland areas as results and interest are generated.

The original plan at CIAT was to use small 5 and 10 horsepower Japanese tillers to prepare about 1/2 hectare per work day. The areas used had not been developed for rice previously, thus a soil movement requirements, the uneven surface, and vegetation made the use of the small tillers impracticable. Finally larger 70 horsepower tractors with large rice and cane tires were used to level and prepare the fields. Some trials during 1973 will use the small tillers on the developed area since the soils have settled and formed a more stable surface and soil profile during 1972.

Land preparation has been the only operation where a power unit is used. Seeds and fertilizers are broadcast by hand. Insecticides and herbicides are applied by a knapsack sprayer, if liquid, and by hand broadcast, if in a granular form.

Intensive, continous, and well paid use of labor has been set as a desirable goal. Time studies of labor required with scheduling for continous land preparation, planting, and harvesting and contract payments per unit of work have given data on labor requirements; these data will permit comparative costing and scheduling with other methods. **Table 1** shows labor machine and material requirements and costs based on the CIAT 1972 data.

Table 2 shows dates of planting, harvesting, area, yields etc. The fields were harvested 120 to 140 days after sowing. These fields could have been immediately prepared and seeded, if adequate water and power were available. The requirements of other CIAT Programs with experimental plots had priority for water and power over the production systems field which explains the uneven scheduling.

Hand harvesting was expected to be the major problem. Since combines are normally used in Colombia, most laborers had no experience with hand harvesting and no special threshers were available. Rice-plot harvests during 1971 had been sucessfully threshed on a 55 gallon drum. The CICA 4 rice variety was easily threshed on the drum with a high apparent output per man hour. A time and motion study **Table 3** indicated that the output averaged 79 kg. per man hour which compares very favorably with 70 to 84 kilograms per manhour reported for a small engine powered thresher especially developed to replace hand threshing. The most important information of **Table 3** is that the major effort is not in threshing but in cutting and carrying which require 62% of the effort. This led to the development of a CIAT man powered portable combine (see a photo) The contract laborers immediately expressed a preference for the portable unit. Since it required less effort, they harvested more per day and received more pay. Two laborers cut, threshed, cleaned bagged, and carried to the roadside 8 to 10 bags of 60 kilograms per day. The CIAT contract labor was paid was 21 pesos or about $0.93 per bag which gave an earned income of $3.72 to 4.65 per man day. Custom combine charges in Colombia are 15 pesos or $0.67 per bag. The contract labor could earn $2.68 to $3.33 per day even if paid combine charges of $0.67 per bag. Since normal wages are $1.00 to $1.50 per day, hand harvesting is an attractive job.

Unit data collected during 1972 in **Table 1, 2** and **3** permit the development of various systems either labor intensive or machine intensive depending upon labor wages, labor availability and objectives. A production system to provide productive employment of laborers and land should be developed for areas that are near to major rivers, roads, ports, and cities such as Barranquilla, Cartagena and Cali in Colombia and for other areas near major cities in other countries such as Guayaquil, Ecuador and Belem, Brazil. The system can be planned using the following data:

1. Land and water are available in blocks of to 10,000 hectares at rental rates less than $50.00 per hectare per year and less than $50.00 per hectare irrigation charges per year.

2. Laborers are available in excess of 10,000 in the area around the major city of 200,000 population with average wage rates of urban and rural laborer less than $2.00 per day and average work rates as given in **Table 1.**

3. Custom hire 70 horsepower tractors and equipment are available at $50.00 per tractor day including operator fuel and all costs. Smaller tillers are not yet widely used but could be obtained.

4. Hand application or custom airplane and helicopters services are available at one manday or $1.50 to $4.00 per hectare per application of seed, fertilizer, and pesticides.

5. Hand harvest or custom

Table 1. Average labor, equipment, and materials required for producing rice on CIAT production fields in 1972.

OPERATION	Man days/ Ha.	Labor Cost-Dollars	Machine and Material Cost
1. Land preparation * with 70 rated horse-power tractor, rototiller and harrow	0.5—1.0	2.00	25.00 to 50.00
2. Construction ** or repair of 640 meters/Ha of levees with 50 cm. top, 75 cm, base and 25 cm high	8.0	16.0	—
3. Clean levees during crop season-640 meters	4.0	8.00	—
4. Broadcast pregerminated seed-100 Kg/Ha	1.0	2.00	15.00
5. Broadcast fertilizer-200 Kg/Ha. of Urea (2 applications of 100 Kg)	2.0	4.00	22.00
6. Application of insecticide Broadcast granules (20 Kg. of 3% active ingredient Furadan)	1.0	2.00	20.00
7. Weed Control.			
a) Handweed one time 30% of area	5.0	10.00	—
b) Knapack sprayer application of Propanil 3.6 Kg. in 100 lts. of water.	1.0	2.00	20.00
8. Irrigation-Maintenance of canals, dikes and keep flooded 100 days by pumping	10.0	20.00	25.00
9. A - Hand harvest 6000 Kg/Ha (cut, carry, stack, handthresh on a 55 gallon drum, clean, bag 100 bags and carry 100 mts. to road)	30.0	90.00	—
B - Hand harvest 6000 Kg/Ha (cut, thresh on portable thresher, clean, bag 100 bags and carry 100 mts. to road)	25.0	75.00	—
C - Combine with medium size, combine 100 sacks and carry 100 Mts. to road 3 man crew and combine for 1/3 day	1.0	6.00	60.00
Summary based on harvest method			
A	62.5	$ 156.00	$ 127.00 to$152.00
B	57.7	$ 141.00	$ 127.00 to$152.00
C	33.5	$ 72.00	$ 187.00 to$212.00

Value of threshed rice at 25% Moisture content and 5% impurities was about $85.00 per ton at the farm roadside where the buyer furnished bags and transportation during 1972. The 6000 Kg. /Ha average was sold for $510.00 per hectare. Returns to land and management would be about $200.00/Ha per crop of 135 days.

* Developmental land leveling and land preparation requires 1.0 manday and tractor day.
** Construction requires 16 mandays.

Table 2. Centro Internacional de Agricultura Tropical Station Operations Production of Rice Cica 4 in 1972.

Lot No.	Date of Seeding	Date of Harvest	Days	Area Ha.	Production Total Tons.	Production Tons/Ha	Production Kgs./Ha. Day
I_2S	6 – XII – 71	18 – IV – 72	134	3.75	19.4	5.17	39
H_2S	15 – XII – 71	26 – IV – 72	133	4.20	21.8	5.19	39
J_1S	12 – I – 72	24 – V – 72	133	1.80	9.2	5.11	38
K_1S	14 – I – 72	26 – V – 72	133	1.80	12.2	6.77	51
G_2S	11 – II – 72	12 – VI – 72	122	3.50	25.1	7.17	59
H_1N, I_1N	12 – II – 72	26 – VI – 72	135	7.45	50.0	6.71	50
	18 – II – 72	6 – VII – 72	139				48
G_2N	11 – III – 72	18 – VII – 72	139	4.00	19.5	4.88	35
H_2N	11 – III – 72	24 – VII – 72	135	4.00	17.7	4.42	33
I_2N	29 – III – 72	2 – VIII – 72	126	2.54	15.3	6.02	48
H_1S, I_1S	28 – IV – 72	31 – VIII – 72	125	3.00	20.3	6.77	54
H_2S, I_2S	12 – V – 72	22 – IX – 72	133	7.00	36.0	5.14	39
F_1	23 – V – 72	28 – IX – 72	128	8.80	50.5	5.74	45
D_1	26 – V – 72	4 – X – 72	131	8.80	66.8	7.59	58
Total				60.64	363.8		
Average			132			6.00	45

Table 3. Average values to hand harvest - cut, carry, stack, thresh on 55 gallon drum, clean, and sack a total of 48.4 tons paddy at 25% moisture content from a 9.6 hectare area.

Operation	Total Man Hours	Man Hours Per Ton.	Man Hours Per Hectare	Percent
Cut & Lay	1059	22	110	44
Carry and stack	430	9	45	18
Thresh	611	13	64	26
Clean and bag	296	6	31	12
Total	2396	50	250	100

combine services are available at $0.67 to $0.93 per bag of 62 kilograms.

6. Trucks for transportation are available at $0.05 per ton-kilometer.

7. Productivity of paddy at harvest ranges from 30 to 60 Kg./Ha-day with an average of 45 Kg./Ha-day (**Table 2**).

8. Paddy sales price at farm with 25 percent moisture content and 5% impurities is $85.00 per ton with sacks supplied by purchaser.

9. Temperatures, irrigation, rainfall, and other conditions permit continous planting and harvesting during entire year.

10. Consumption of rice is expanding to replace cassava, plantain, corn, potatoes and wheat in local diet.

With the conditions as given then a mixture of labor, land, machinery and materials must be developed to farm a production system. If one major condition is to provide productive employment and about 60 mandays are requried per hectare distributed as in **Table 1**, then we can plan for continous stable employment and production with 120 mandays of work during a 140 calenderday drop cycle.

One man can care for 2 hectares by planting and harvesting 0.2 hectares every 14 days. His labor input per 14 days period would be 12 days of which 5.6 days would be on levees, weed control and irrigation; 0.8 days on seeding, fertilizing and insect control and 5 days on hand harvesting.

The smallest complete operation system would be based upon a contract hire service for land preparation and marketing based upon a 5 horsepower tractive tiller and implements. The 5 horsepower tractive tiller should prepare 0.2 of land per day to service 12 farmers during a 14 day period. The tiller could also transport the freshly harvested 1200 Kg. per day of paddy to a central pick-up point for sales transport to market by a truck. The next complete operation system would use a 10 horsepower unit which should prepare 0.4 hectrare of land per day to service 24 farmers during a 14 day period and transport 2400 Kg. per day to a central pick-up point.

These two small systems would permit full utilization of labor and tractive tiller time under a very tight schedule. In case of delays due to sickness or tiller repairs then extra labor and equipment would need to be hired to maintain the schedule. The attractive feature is a continous cash flow from the sale of 1200 Kg. of paddy 14 days for a gross farm sales value of about $100,00. Expenses for 0.2 hectare should be approximately $10.00 land preparation, $3.00 for seed, $5.00 for fertilizer, $8.00 for pesticides, $5.00 for irrigation and $5.00 for rent. The extra $64.00 would be returns to labor and management of approximately $128.00 per month and $1.536.00 per year to the operator of a 2 hectare farm unit. The owner of the power tiller should have as attractive an income as the farm operators.

If his equipment expenses were $25.00 per hectare and wages $25.00 per hectare then the 5 horsepower tractive type tiller owner would make $5.00 per day or $120.00 per month and the 10 horsepower rotary tiller operators would make $10.00 per day and $240.00 per month. This potential income should attract capital and operators and be of interest to manufacturers of small power units and to government planning groups as a potentially desirable production system, however the small farm operator custom hire service is not now in existence and the initiative cooperation, and management skills to implement the system are not easy to obtain.

A more likely solution would be a 60 hectare commercial farm enterprise organized by an experienced rice farmer. This enterprise would be based upon a 70 horsepower tractors preparing 3.0 hectares of land per week, transporting the harvest to market, and returning with materials and supplies. The farmer could also be the tractor driver, supervisor and manager. He would employ about 30 laborers paid by contract to earn about $25.00 per man week. His gross sales should be about 18,000 Kg. of paddy per week or $1,430. 00. His costs would be about $750 labor, $45.00 seed, $65.00 fertilizers, $120.00 pesticides, $150.00 equipment, $75.00 irrigation and $75.00 land rental for total costs of $1,280.00 per week. His potential returns for his labor and management would be $250.00 per week or about $13,000 per year. The yield of 6,000 Kg. of paddy at 25% moisture content is not difficult with reasonable water control and management and the farm price of $85.00 per ton has been paid CIAT during 1972. The risk involved is that lower yields or prices would result in losses and any rice grower considering this system must be aware of that importance of production and price relationships. The costs of land, water and equipment, however leave considerable leeway for production and price fluctuations before seriously endangering the cash flow to labor and management. It should be emphasized that the employment of 30 laborers at $25.00 per week average contract wage would be economically and socially desirable in most tropical countries. The larger farm size would attract Professional management talent and the use of laborers would permit hand harvest during weather when combines would not work. When laborer wages exceeds about $25.00 per week then combine harvest would likely be substituted and the labor crew reduced to 15 men and the equipment increased to add one combine at the cost of $45.00 per day to harvest 0.5 hectare. The loss of employment opportunities and the foreign exchange cost for combines would be a serious consideration at the national level. However the farm size in many of tropical America areas can be increased to 120 hectares and maintain the same labor crew at higher wages. The combine would be attractive in reducing per hectare cost of labor housing, — transportation, and management. There is also the possibility that harvest losses could be minimized if the farm manager also operated the combine.

The commercial 120 hectare farm with a combine, a 70 horsepower tractor, implements, and trailer could be operated on a continous basis by the farm manager and 32 laborers to prepare plant and harvest 6.0 hectares per week. The tractor would be used 5 days or less per week and the combine 2 to 4 days per week. Laborers would be used largely for levee maintainance, irrigation, seeding, fertilizing and pest control. The Break down of costs would depend largely on wage rates. Suppose that wages are $40.00 per manweek and $1,280.00 per week for the 32 laborers, and other weekly costs are combine $300.00, tractor and equipment $300.00, irrigation charge $150.00, land rental $150.00, seed $90.00, fertilizer $130.00, pesticides $240. 00, for total costs of $2,640.00 per week. If gross production is 36 tons at $85.00 per ton then gross sales of $3,060.00 per week leave an income to management of $420.00 per week which is very attractive especially if rent is considered.

The production systems outlined are illustrations of the potential production and employment opportunities for management, machine operators, and laborers working together daily; each performing his part and participating in an income from continous utilization of the available resources. No one method is universally good, however, the availability of land, water, favorable temperatures, and labor supply that are under utilized should lead to the organization of rice production systems in some of the tropical American areas which will set patterns for the future. The other implication is that there are obviously potential advantages in sizing units to reduce the equipment and managerial costs per hectare. ■ ■

Soil preparation with 6 hp hand tractor used in intensive cropping systems.

Increasing Water Use Efficiency in Multiple Cropping

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Tropical and sub-tropical agriculture affords opportunity for growing two or more crops per year, provided there is water. In India, double cropping such as 2 crops of paddy or maize-wheat and similar rotations have been practised since long in areas with assured irrigation. About 50 per cent of the cultivated area in India is tilled by farmers possessing 5 hectares or below of area. Unemployment and under-employment have long been the scourages of rural areas. A vital task before scientists engaged in the task of providing tools for agricultural transformation is the development of techniques which can help to increase the income and employment potential of small holdings without detriment to the long term productivity of the soil.

Multiple cropping or the cultivation of two or more crops per year on the same piece of land can increase the economic yield per unit of land area, time and water. They lead to better employment of the rural population, higher per capita income and general prosperity of the people. Sound techniques of multiple cropping not only improve crop productivity without detriment to the long-term production potential of the soil but also with a view to continuously improve the physical, chemical and biological properties of the soil. The major scientific ingredients necessary for the success of multiple cropping are the availability of relatively photo-and thermo-insensitive crop varieties, proper tillage, irrigation, nutrient supply and other agronomic practices, integrated techniques of pest control and appropriate post-harvest technology, particularly storage and marketing. As the available water resources are usually limited in the tropical and sub-tropical countries, the effort should be to maximise production per unit of available water.

Increased water supply and improved water management are the important aspects of irrigation development in India in the future. Great strides in the evolution of high yielding varieties of crops and multiple cropping techniques have raised the demand for water which is the most dominant factor limiting agricultural production. We need more water to bring in more area under irrigation and for intensive agriculture. Increasing industrialisation, population growth and better standard of living of the people have increased the need for water. The water resources of India and other tropical countries are usually limited and cannot sustain indiscriminate exploitation. As more and more water get harnessed and committed, there will be increasing competition for available supplies between agriculture, industry and

A submersible pump installed in a tube well drilled to over 300 metres depth in Hissar district of the State of Haryana. There has been a break-through in ground water exploration through open wells and tube wells since the advent of the green revolution.

other users. This calls for efforts to conserve the available resources and utilize them for maximum benefit to the people on a sustained basis. The aim of the agricultural scientist today is to produce maximum crop yields per hectare, per day, per unit quantity of water and conserve the productivity of the land.

The increase in irrigated area in India, which has nearly doubled during the past two decades, has been mainly by the increased use of surface water resources by constructing reservoirs and canal networks. In the recent years there has been a rapid increase in the number of irrigation wells. The attention of our irrigation engineers, till recently, has been confined upto the canal outlet, where water is delivered, but has, by and large, not been related to the qualitative and quantitative aspects of water use on the farm. The traditional irrigation system is mainly for extensive farming and not adapted to the modern intensive agriculture with high yielding crop varieties and multiple cropping techniques. The water delivered per unit area under the command of canals is often not adequate to meet the requirements of successful agriculture. It is estimated that the area under the command of canals receives only about one-third to half the water required for intensive agriculture. Generally speaking, the land close to the water course inlet gets a greater proportion of water than the land at some distance.

Many land and water problems of grave importance confront our irrigated agriculture. Large quantities of rainfall-runoff are lost as a part of the river flow which cannot be harnessed for irrigation. Substantial quantities of water harvested from watersheds, pumped from ground water sources, or diverted from streams are lost by seepage and evaporation from tanks, reservoirs, canals, distributories and field channels. Inadequate design information and improper construction methods lead to low yield of irrigation wells. Wells and pumps are often not matched, resulting in inefficient use of the water resource and loss of energy in pumping. Inadequately or improperly designed field irrigation systems and uncontrolled water application methods are leading to huge losses of water by seepage and deep percolation which represent the loss of a valuable resource developed at high cost. In many cases, not only is the loss of water of concern but the damage it creates by waterlogging and accumulation of harmful salts is considerable. Water supply is often not tailored to suit the requirement of the crop or the cropping pattern does not suit the possible water supply.

Integrated development of water resources, efficient methods of conveyance and distribution of water on the farm, suitable methods of water application and the removal of excess water from the crop root zone are the important aspects of a comprehensive irrigation development programme. Successful irrigated farming involves the interaction of the soil, the water and the crops grown. The amount of water applied and the interval between successive irrigations depend on the extensiveness of the root system, stage of plant growth, water storage properties of the soil, transpiration properties of the crops and weather factors which influence water loss by evaporation. Irrigation projects cannot be considered complete until well engineered provisions have been made to apply water efficiently at times and in amounts consistent with plant growth requirements and adequate arrangements are made to remove surplus water wherever necessary.

Planned Utilization of Water Resources

The average annual rainfall of India, based on an average rainfall of 112 cm, works out to be about 370 million hectare-metres. Of this, it has been estimated that about 120 million hectare-metres of water are lost by evaporation, about 80 million hectare-metres seep into the soil and about 170 million hectare-metres flow into the rivers. Out of the 80 million hectare-metres of water that seep down annually into the soil, about 43 million hectare-metres remain in the top layers and contribute to soil moisture which is essential for the growth of vegetation. The remaining 37 million hectare-metres percolate down and represent the annual enrichment of ground water.

Ground Water Resources. The ground water resources of India have not been fully explored and utilised. Out of the utilisable resource of about 26 million hectare-metres of ground water available from annual recharge, only about 11 million hectare-metres are utilized through wells at present. The development programe for ground-water under the Fourth Plan aims at utilising an additional 5.3 million hectare-metres of water. There is, thus, a surplus of about 10 million hectare-metres of ground water for future development from the annual recharge alone, which can irrigate about 12 million hectares of additional area. There is an additional component of ground water recharge from canal seepage. The total annual canal seepage in India is estimated to be about 45.5 million hectare-metres.

A substantial quantity of rainfall-runoff which is lost as river flow may be used to recharge our ground water reserve. In the arid and semi-arid regions, excess stream flow during the rainy season could be saved as ground water for use in dry seasons by diverting the stream flow into basins, pits, furrows and recharge wells. Adoption of soil and water conservation practices will lead to increased opportunity time for the runoff of water to infiltrate into the soil, thus enriching the soil moisture and ground water reserves. Deep tillage opens up the soil and facilitates infiltration and storage of rainfall water in potential crop root zone.

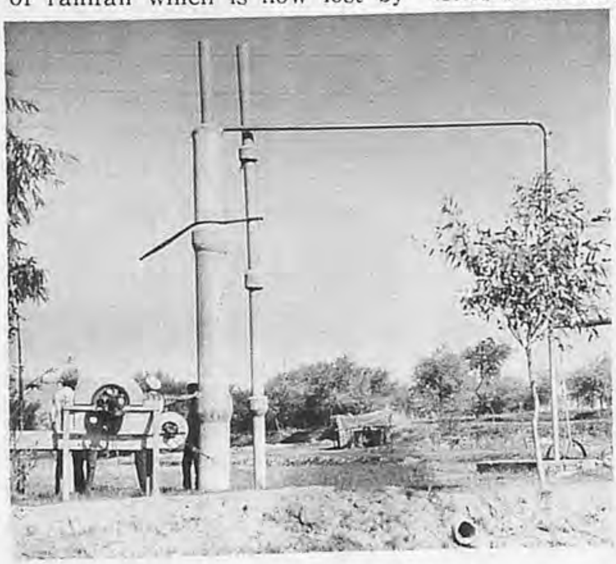
Surface Water Sources. It has been estimated that out of about 170 million hectare-metres of river flow, only one-third can be utilized for irrigation because of the limitations imposed by topography, river flow characteristics, climate and soil conditions. Only about 16 million hectare-metres of water from river flow is utilised and present. Another 6 million hectare-metres are likely to be utilised for irrigation during the Fourth Plan period. There is, thus, a utilisable surplus of 32 million hectare-metres of water for future development which could irrigate another 40 million hectares of land.

Rainfall Harvesting. New water supplies can be developed in the arid and semi-arid regions of the country by capturing a portion of the tremendous volume of rainfall which is now lost by runoff, seepage and evaporation. Water harvesting is a process of collecting and storing water in low rainfall areas. Small selected watersheds are treated to increase rainfall-runoff. The stored water can be used for supplemental irrigation.

Large quantities of water collected in tanks and reservoirs are lost by seepage and evaporation. Plastic, artificial rubber and chemicals could be used successfully for lining and covering storage reservoirs to stop seepage and evaporation losses. Water-borne asphalt emulsions are effective in preventing seepage from reservoirs. Seepage from unlined reservoirs in calcium aggregated soils can be greatly reduced by treatment with sodium salts. The efficiency of a sodium salt can be substantially increased by mixing it with bentonite in suitable proportions. The sodium bentonite that disperses and swells, blocks the water-conducting soil pores effectively.

Increased Efficiency in Lift Irrigation

Efficient and economical utilization of ground water through wells depends on the design of wells to suit best the characteristics of the water bearing formations. Flow of ground water into wells is influenced by the physical characteristics of the water bearing formation, the extent of this formation, the elements of well design and the methods used in constructing and developing wells.



A high-head pump stand and vent pipe installed at the head end of an underground pipeline water distribution system in a hilly tract in the Rupar district of the State of Punjab. Note the pump delivery pipe feeding the line through the pump stand. Underground pipeline irrigation distribution systems are becoming increasingly popular in areas irrigated by wells.

Tube wells may be deep or shallow. They may be screened wells or cavity wells. Screened wells are often provided with a gravel envelop around it. The selection of one or the other type of wells depends on the nature of the underground formation. Faulty design and construction practices lead to failure of wells and loss of the huge amount of money invested. For instance a cavity well constructed at a place where a screen well is suitable, is bound to fail. However, when a rich water bearing sand formation lies below a thick clay layer, a cavity well, consisting of a simple bore lined with a pipe reaching the water bearing layer and a small cavity formed around the bottom of the pipe, will produce high discharge wells at a low cost. Similarly, in many instances a battery of shallow tube wells connected to a common pump may be far more economical and efficient than a deep tube well drilled at a high cost.

Simple tools and techniques are available to enable the farmer to construct low cost shallow and moderately deep tube wells. In some places an open well may be more suitable than a tube well because of the large storage space available in open wells. In many cases the yield of existing open wells can be increased adequately by driving lateral bores in the fissures in the rocks encountered below water table or by sinking bore holes from the bottom of the open wells. These lateral or vertical borings in open wells can be done with low cost indigenous boring tools consisting of sharp pointed or twisted bits and extension pieces.

The discharge of wells is related to the extent the water table is lowered by pumping. Well yields at different depths of pumping may be obtained at the time of testing a tubewell after completion or by a separate test pump. Lack of information on well yields has often result in the improper selection of pumps and low yields.

The discharge and efficiency of a pump depend on its design. It is a common sight to see pumps consuming huge amount of power and delivering a small quantity of water. The farmer must ensure that the pump he selects to purchase has the desirable characteristics. As the pump characteristics very widely, it is possible to select a pump which suits best a particular site condition. Not only the selection, but the installation of pumping sets to suit the widely varying field conditions is important.

Increased Efficiency in Water Conveyance and Distribution

Loss of irrigation water occurs in the conveyance and distribution system. The loss may be either by seepage or by evaporation. Evaporation losses, however, are negligible in an irrigation water conveyance system. The loss, however, is considerable in tanks and reservoirs.

The loss of water in water courses and field channels may occur by seepage in unlined channels, by loss through holes bored by rodents and insects, and loss by breeches in channels. The seepage loss in a channel is directly related to the wetted perimeter of the water course and its length. It depends on the condition of the channel, the type of soil in which it is constructed, whether the land is infested with rodents or not and the design of the channel cross-section. It is estimated that the seepage loss in water courses receiving water from canal outlets ranges from 25 to 40 per cent in the sandy loam soils.

The lining of water courses and field channels is the answer to overcome the immense loss in field channels and water courses. This will reduce the sufferings of the farmers at the tail end of a water course in a canal system. Lining will ensure equal distribution of water amongst all farmers in the 'cultural command area' of a water course. Lining will also make available more area under irrigation by raising the level of the water course, by reducing the area of land occupied by it as compared to an unlined channel and by saving water. Lining is especially important under lift irrigation system as the cost of lifting a unit quantity of water is very high in this case as compared to that of canal irrigation.

The followings are the materials which can be remmended for lining water courses and field channels.

1. Lining of water courses from canals: Brick lining (preferably rectangular section with about 6 mm thick cement plaster).
2. Field channels having capacity upto about 30 litres/second (1 cusec approx.): precast concrete irrigation channels and underground pipeline water distribution system using RCC pipes.

Water Application Methods

The quantity of water supply, the type of soil, the topography and the crops to be grown determine the correct method of applying irrigation water. Irrigation water may be applied by controlled surface flooding methods, by the sprinkler method and by the drip method. Whatever be the method of irrigation, the essential requirement in water application is to apply the right amount of water to distribute uniformly on the field and to wet the rhizosphere soil to its storage capacity. Due to injudicious methods of irrigation, considerable amounts of irrigation water are lost by percolation below the crop root zone. This is not only a loss of valuable water but also a loss of plant nutrients due to leaching. The ultimate result is a rise in the water table, making the soils saline or alkaline.

A chute spillway constructed with precast concrete channel sections is used to convey water down to a lower adjoining field at non-erosive velocity. Note the check gate installed at the inlet of the spillway.

The common methods of surface irrigation are the check basin, the border strip and the furrow. High water application efficiencies may be obtained by any one of these three methods, if the system is properly designed. Recent development in surface irrigation research has made it possible to predict the behaviour of the irrigation stream on the land surface and apply precise amounts of water to the crop.

Sprinkler Irrigation. Sprinklers have advantage over the surface methods mostly on the hills, especially in plantation, as the method requires little or no land levelling and can be adapted to irrigate standing crops. Under the average conditions of soil and topography, the cost of land grading and installation of lined field channels and the cost of laying a sprinkler irrigation system are nearly the same. The maintenance and operation cost of the sprinkler system is comparatively very high due to the additional energy required to force the water through the sprinklers and the depreciation of the component parts of the system. Investigations have revealed that both the sprinkler and the surface methods of irrigation could be used efficiently, if designed properly.

Drip Irrigation System. The recently developed drip irrigation method offers a challenging opportunity to reduce the total water required for irrigation under many field situations. In the drip method, water is conveyed through flexible pipes and applied to the field through drip nozzles through which water drops into the soil. With the drip method it is possible to irrigate frequently and apply precise amounts of water to the crop. Water loss by surface evaporation and deep percolation are reduced to the minimum. The method, though costly on a comparative basis, would be most suitable in areas of water scarcity and is likely to prove economical for irrigating orchards, vegetable and cash crops.

Inadequate drainage, poor field layout, high losses due to deep percolation, and inadequate irrigation at critical periods are the chief water management problems facing the low-lying rice growing areas.

Soil Management for Efficient Water Use

Soil management practices aim at obtaining uniform distribution of irrigation water on the farm, storing large quantities of rain water within the crop root zone and improving the soil structure for increased water availability. The most important soil management practices in relation to irrigation are land grading, land preparation and cropping practices.

Land Grading. Efficient surface irrigation is impossible without a smooth land surface for uniform distribution of water. Land shaping is necessary in making a suitable field surface to control the flow of water, to check erosion and provide for drainage. Land grading operations involve land levelling and the smoothening.

Land Preparation. Land preparation involves tillage practices that would develop a good seedbed for seed germination and seedling emergence and an adequate root bed to permit normal root development and a reasonable rate of water infiltration. It may also involve elimination or prevention of plough soles and compacted layers which could limit root development.

Tillage practices in unirrigated areas aim at storing large quantities of rain water within the crop root zone and its increased availability to crops. Moisture storage in the soil is a function of the infiltration characteristics of the soil, available infiltration opportunity time and other physical and chemical properties of the soil. Many of these may suitably be modified to increase the amount and availability of moisture required for the crop growth. Field practices like contour farming and other conservation tillage and cultural practices, contour bunding and terracing reduce the velocity of runoff water and allow larger time interval for the water to infiltrate the soil.

Cropping Pattern. Inter-cropping of deep and shallow rooted crops alternately decreases the competition of the rooting pattern for moisture absorption and ensures maximum utilization of water. It seems desirable to grow deep rooted oil seed crops like sunflower alternately with comparatively shallow rooted leguminous crops like pulses, a practice that improves substantially the soil structure as well as water use efficiency.

Irrigation Scheduling

Water requirements of crops vary with the crop and its variety, soil conditions, fertilizer schedule and climate. Each crop has certain critical stages at which if there is a shortage of moisture, yield is reduced drastically. It is well known that in the Mexican varieties of wheat, the crown root initiation (about three weeks from sowing) is a critical stage. It has been observed that regardless of the depth of planting the crown nod develops about 2 cm below the surface of the soil. If the soil zone around the crown is dry at the time of the crown root initiation, crown roots do not develop properly and only

(Continued on p.105)

Established Internat. Center for Research on Vegetables in Taiwan

The Asian Vegetable Research and Development Center (AVRDC) is a newly established international center for research on vegetables. It is located 20 kilometers north-east of Tainan, Taiwan, near the village of Shanhua. At this stage in the Center's building program an administration-office building, laboratory building, service building and eight staff houses have been constructed. Work is beginning on the erection of six green-houses and an adjoining head house. The total land area available for the Center's field program is 116 hectares.

The principal objective of the AVRDC is to solve the most important problems of vegetable production in the humid tropics and sub-tropics of Asia through an intensive research and training program. Some of the more obvious of these problems are: 1) the high seasonality of vegetable production, and consequently supply, 2) the high incidence of disease and insect pests especially during the rainy season, 3) lack of adaptability of many important and nutritious vegetable crops to the climate of the lowland tropics, 4) inadequate and undependable supplies of seed, 5) unsatisfactory methods of handling storing, preserving and marketing vegetables and 6) low productivity due to the use of antiquated cultural practices including inadequate use of fertilizers and poor control of weeds, diseases and insects. It is believed that the solution to these problems can be achieved largely through the creation of new varieties much better adapted to the adverse environment of the humid tropics with resistance to pests, and by the development of superior methods of crop management, preservation and marketing.

The group of plants commonly called vegetables includes many species and it would be impossible to make a significant impact on the problems of any one species if the Center's efforts were diffused over the entire group. For this reason, crops priorities have been established. Vegetables which are widely grown in Asia and are outstanding sources of either energy, proteins, vitamins or minerals, have been selected for emphasis in the initial program of the Center. For some crops, a world-wide collection of available germ plasm will be made and the resulting plants evaluated; in other cases improved production methods will be studied to increase crop yield and quality.

Priority will be given to the following crops: Chinese cabbage and radish, mung beans, sweet and Irish potatoes, sweet corn, water convolvulus, onion, tomato and egg-plant.

To achieve the objectives of crop improvement a group of scientists, mostly Asians, are now being employed to work in the areas of varietial improvement, plant protection, crop physiology, soil management and fertility and seed production. After the initial staff is gathered, additional scientists will be employed in agricultural chemistry, production and marketing economics and post harvest physiology and food technology.

A training officer will be responsible for developing the training program of the Center at a future data. It is anticipated that trainees from the several countries in Asia will be selected to receive training at the Center in improved vegetable production techniques.

The Center is establishing co-operative arrangements with the International Institute for Tropical Agriculture in Nigeria for work on sweet potatoes, and with the International Potato Center in Peru for work on Irish potatoes. Similar linkages will be established with other international and national institutions for exchange of plant materials and research information.

The activities of the Center are directed by Dr. Robert F. Chandler Jr., the former director of the International Rice Research Institute in the Philippines.

(by R.F. Chandler)

TOPICS

NEW BOOKS

Economic Analysis of Agricultural Projects
by J.Price Gittinger

Perhaps the most difficult single problem faced by agricultural administrators in developing countries is implementing development programs. Much of this difficulty can be traced to poor project preparation.

The purpose of this book is to sharpen the pre-investment analysis tools of those people in developing countries who have responsibility for spending scarce money on agricultural development. The author discusses practical ways to help ensure that when investment decisions are made, capital will be used economically and efficiently.

The book does not deal with agriculture itself or with those aspects of project preparation and evaluation which rest on the skills of agronomists, livestock specialists, and the like. It is a straightforward spplication of what are known as most probable outcome discounting techniques to compare alternative agricultural development projects. Such knowledge of economic analysis will prove invaluable to agriculturists and other professionals involved in project planning.

221 pages. Price $10.00 (cloth), $3.00 (paper). Available from bookstore and The Johns Hopkins University Press, Baltimore, Md. 21218, or Hopkins' agents.

Recent Research on Multiple Cropping
Indian Agricultural Research Institute

Published by IARI as a research bulletin, New Series No.8.

Umemployment and under-employment have long been the scourges of rural areas in developing countries. Therefor, a vital task is the development potential of small holdings. Multiple cropping or the cultivation of two or more crops per year on the same piece of land is obviously a technique which can lead to more income as well as reduction of under-and un-employment.

IARI initiated long term experiments on multiple cropping in 1966. This book containing a summary of the results obtained during the past six years deals with multicropping in relation to cropping patterns, soil management, plant protection, farm machinery & implements and rural employment. Moreover it refers to an economic study and place of multi-cropping in the national demonstrations.

148 pages, 17.3 × 24.2cm, soft cover. Indian Agr. Research Institute, New Delhi, India

Vegetable Production in Southeast Asia
Edited by James E.Knott and Jose R.Deanon, Jr.

This book is the first of a series of college-level texts that the U.P. College of Agriculture hopes to publish. It differs markedly from other books on vegetable growing that have been written in Southeast Asia. It presents the scientific background for the responses of vegetables to their environment and to the cultural techniques that can be used in their production. An extensive bibliography covering some of the researches relevant to the behavior of vegetables in the Tropics is provided. Many of the entries are available internationally, but others are unpublished researches pertinent to the subjects discussed.

The materials in this book aim to give the reader an understanding of the factors that must be considered if vegetable production is to be increased to meet the dietary needs of the exploding population of Southeast Asia.

University of the Philippines, College of Agriculture, College, Los Banos, Laguna, Philippines

Vegetable Production in the Sub-tropics and Tropics
(Text-Book Series No.25, OTCA)
by Kiyohiko Kinoshita

The amount of vegetable consumption in the developing countries has not yet reached a satisfactory level from the health point of view. Vegetables and fruits have high nutritive values of vitamin. But vegetable production provides farmers with a very reasonable means of maintaining their economy. They are the crops which require the most intensive and the highest level of technique among many products.

The purpose of this manual, prepared as part of technical cooperation, is aimed at providing guidance on vegetable production techniques to the readers of field experiments who are not necessarily provided with sufficient texts or reference materials on the subject. The manual is based on the experience and results of research the writer has undertaken in the tropics. It is to be distributed to the Farmers advisor and the relative staff to Vegetable Production in foreign countries as part of OTCA's overseas technical cooperation project.

318 pages 21 × 29.5cm, soft cover. Overseas Technical Cooperation Agency Honmura-cho 42, Ichigaya, Shinjuku-ku, Tokyo, Japan

The Trend of Pesticides Applicator in Study

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The vector control techniques are dependent on many factors: knowleges of the susceptibility of vectors to the various pesticides available, selections of an appropriate applicator, judicious timing of the applications, adequate precautions against the toxic hazards to men and animals. Especially, the availability of properly designed applicators for the dispersal of pesticides selected is should make certain that the effect of controls, the capacity for dispersals, the safety at works, and the saving of labors seem to approximately satisfactory as expected, because of the strongest dependence is observed between the machines for applying and the formulations of pesticide in recently. The applicators belonged to manually-or power-operated are divided into sprayer used hydraulic energy for the liquid pesticides, mist-sprayer, air-blast-sprayer, and ultra-low-volume-sprayer used gaseous energy for the liquid pesticides, and dusting-equipment or granule-applicator used gaseous energy for the solid pesticides. The majority of possession of manually-operated-applicators is private for the easiness of operation to control the various insects and fungi of the diversified crops in the small fields. But the judicious timing of vector controls has a tendency to lose, because the applicable areas in a day by this manually-applicators have a limit in the extensive fields as many researchers concluded.

The concurrent works of dispersal used tractor-trailled or mount-type-power-applicators show the remarkable effects of prevention and extermination to the vectors with the appreciable savings of labor in the extensive fields. The works are usually done with the co-operative or contract forms under the public encouragements after forecasts of vectors.

I. Savings of labor and high capacity applicators

In the regions that the supplying of abundant labors is possible, the savings of labor to dispersal are out of discussion. But in the agricultural areas at the neighborhood of the other industrial zones that pay the expensive wages cannot avoid the decreasings of product by the unsufficient controls of vector due to the scarcity of labor. For the dispersals by the saved labors in the extensive areas at a judicious timing for vector control, it is necessary that the high capacity applicators are usually prepared with the schemes of work and the selected pesticides. The capacity (ha/hr) of applicators that decided by the judicious days for a vector control (1-3 days), workable hours in a day which include the preparation, adjusting, supplying and rest hours (2-6 hr), and the areas of dispersal in the every controls (ha) are obtained by the calculation showed a next formula.

$$\text{capacity} = \frac{\text{(areas of dispersal)}}{\text{(judicious days)} \times \text{(workable hours in a day)}} \text{ ha/hr}$$

In the assumptions of manually-operated-applicator (knapsack-type), areas of dispersal are 0.8 ha, judicious days are 2 day, workable hours in a day are 4 hr, and number of operator is 1, the capacity of applicator is 0.1 ha/hr, and 0.1 ha/hr-man. For power-operated-applicator that tractor-mount, areas of dispersal are 16 ha, judicious days are 2 day, workable hours in a day are 4 hr, and numbers of operator and follower are 5, the capacity of applicator is 2 ha/hr, and 0.4 ha/hr-man. As the result of this comparison, the capacity of power-operated is 20 times, and capacity per man is 4 times that of manually-operated. It is clear that power-operated is not only

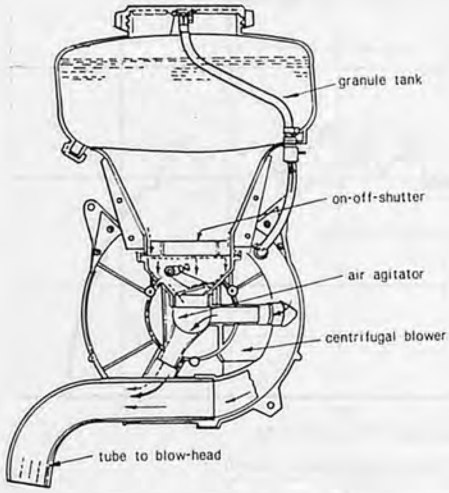

Fig.1 structure of knapsack-power-granule-applicator

Fig.2 granule application by boom-type-blow-head

higher capacity but more effective for the savings of labor.

The encouragements of power-operated-applicator cause the over-investments against the agricultural managements of farmer when the scales of management are small, and the yields are lack. The positive coordinations with subsidy for the encouragement of power-operated, however, are necessary to the groups of farmer in districts that the modernization of vector controls are desired.

2. Developments of applicator and pesticide

1) Granule-applicators and it's attachments

It is difficult for the increasing of capacity to the liquid-applicators except ultra-low-volume-sprayer, because the times and labors of water-supply and dilution of liquid cannot easily save at the districts where the distances to pond or river are far across the fields. On the contrary, the dispersals of granule for solid pesticides are done as soon as the pesticide supply in the tank, so that capacity of applicator and the easiness of work increase on comparing with the other applicators. For the proceeding to utility, the studies of development of the granule-applicators started around 1960. The granule applicators whether it is knapsack-power or tractor-mount-power-type consist of a granule tank without the mechanical agitator in the bottom, an on-off-shutter that slides on the marks of each discharge rate, an air agitator that is the chamber for mixing the granule and a part of air-blow that led from the blower, a centrifugal blower that delivers the high speed air-blow, a tube that joints the outlet of blower to blow-head, and a blow-head hat disperses the granule to crops with air-blow as **Fig 1**.

The structures of knapsack-power-granule-applicators are much the same to dusting-equipments, and it is changeable from dust-equipment to the granule-applicator with re-adjusting of small lever situated in bottom of the tank. The boom-type-blow-head that developed for the granule application showed in **Fig 2** shapes the long band (20-30m) made by the thin plastic sheet, and gets into the long pipe as soon the air-blow flows from the blower in to the folded band. This head can disperses the granules with air-blow from the small holes opened at the bottom side and spaced 20-40cm intervals between the operator of the applicator side and follower of the end side of the head, across the upside of fields onto the crops. If the width of the fields is just the same to the effective swath (lengths) of a head, the operator and follower have only to walk on the paths of field as easy as they walk on the road for the dispersals of granule. The evenness of deposits through the swath of commercialized blow-head is sufficient to vector controls as **Fig 3** a **4** by the improvemets followed the studies since 1965.

The conditions of dispersal of this boom-type-blow-head with knapsack-power-operated are as follows: the application rates of granule are 30-40kg/ha, the times of dispersal are 10-15min/ha

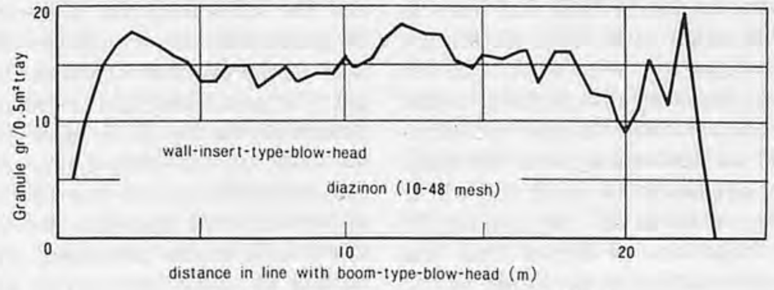

Fig.3 distribution of coarse granule (swath : 20 m)

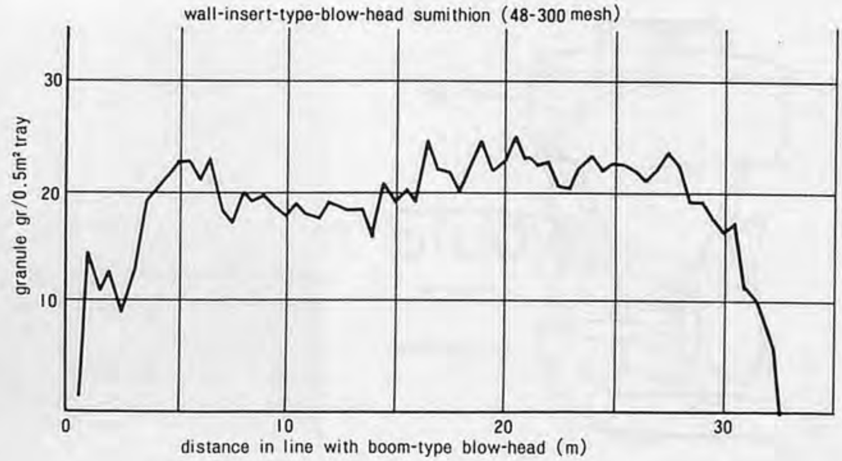

Fig.4 distribution of fine granule (swath : 30 m)

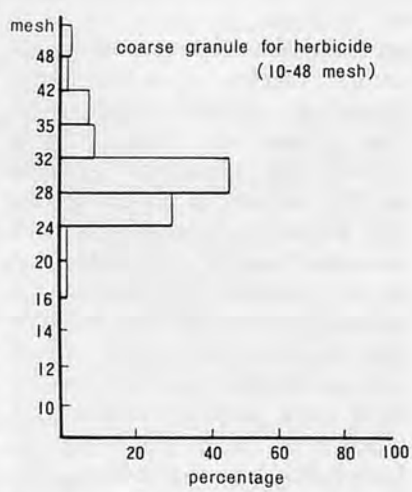

Fig.5 diameter-distribution of coarse granule

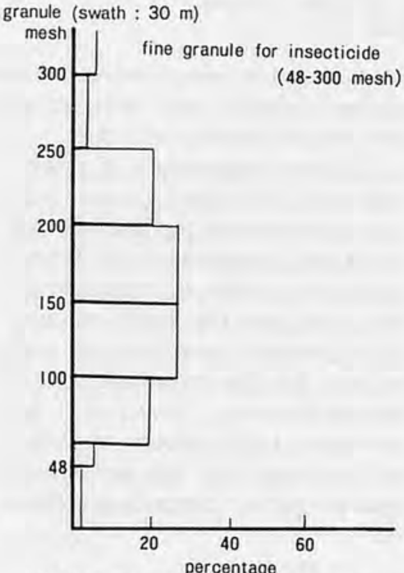

Fig.6 diameter-distribution of fine granule

except adjusting, supplying, and other preparations, the walking speeds of operator and follower on the path are about 0.4～0.6m/sec, and the capacity of dispersal of a applicator is over 4-6ha in a day (2hr/day of works) with 2 labors. It is probable that the capacity of this blow-head is far better than the others.

2) Transition of granule pesticides for the blow-head

A procedure for decreasing of the drift that occurs the crop injury and air pollution was the granulation of herbicides as PCP and CAT for the pre-emergence treatment in the paddy and upland fields, because the dispersed granule that has the spherical shapes and the weights do not deposit onto the stems or leaves of the crop, and not transfer with a breeze in the atmospheric environment. Diameter-distributions of granular herbicides showed in **Fig 5** belong to coarse granule (10-48 mesh), and all dispersed granules fall down into the standing water near the seeds of graminaceous weed in the paddy fields. Subsequently, BHC granules (same range of mesh) that formulated to the insecticide showed the successful control effects for the rice-stem-borer that lives in the stem near the standing water. But the researchers reported that the control effects of the fine granular insecticides (48-150 mesh) as *diazinon* and *sumithion* for increasing of the deposit on the leaves of crops are better than the coarse granules with many data. And the other reports, diameter-distribution that has the wide range as 48-250 mesh for the pesticides as **Fig 6** are better than the other distributions to the vector control, because the cures and preventions against the fungi are necessary to cover the whole body of crops by the granules. It is important problems that the determination of allowance of the lower limit for the diameter-distributions of granule is necessary for the vector controls as far as the obstruction of drifts are tolerated.

As a formulation of granule is proved the high vector control effects by researchers, the other pesticides of the dust or liquid transformed into the granules with the spread of the granule-applicators. The granulations by mixing of the pulverized carrier and the solid technical materials of pesticides are comparatively easy in the process of production, but the pesticides that technical materials are liquid (is especially oil-base) are not simple, because the absorbability into the carrier of the technical materials has the limits without any adjuvants. The mixing of pulvelized carrier and solid technical materials before making to the granules, the dipping of liquid materials to the granulated carrier, and the coating of liquid to the granulated carrier are adopted for the granulations by the formulators of the pesticides makers.

3) Connection of applicators and granules

It has the close relation between the applicators and the granules. The irregulality of discharge through the bottom of granule tank to the adjusting or on-off-shutter can indirectly indicates by the angle of repose of granule. If the angles of repose are over 50-60 degree, the bridge that shapes a cave breaks out at the bottom of tank and disturbs the discharge of granules to the adjusting or on-off-shutter.

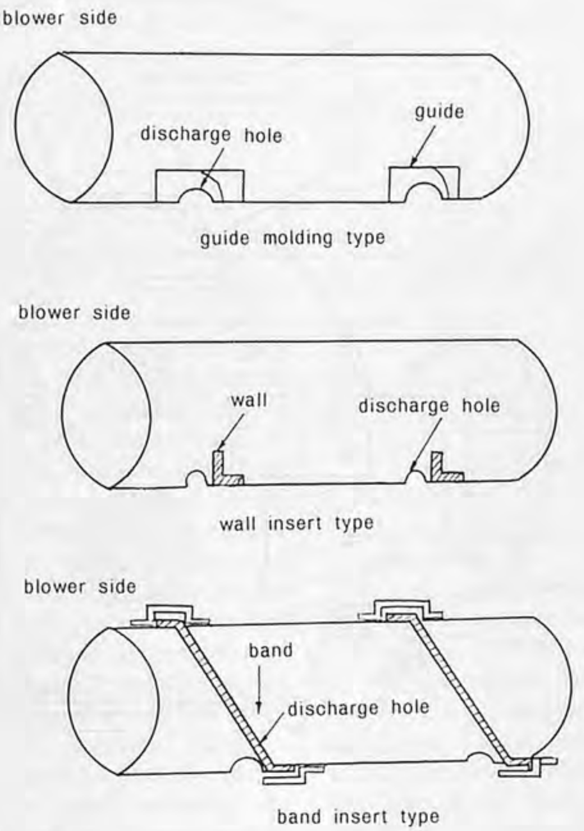

Fig.7 boom-type-head

Another problem, the discharge rate by a opening of shutter and the longitudinal evenness by dispersal of a boom-type-blow-head are not just the same against the varieties of granule of which the diameter-distributions are different in each products.

The checks for successful discharge of the granule from the blow-head are requisite to the operations of applicator as well as the dispersals of the other applicators. But the dispersed granules from the blow-head are not visible in contrasted with the clouds of dust delivered from dusting-equipment. The situation of on-off-shutter-lever should be fixed on the adequate mark coincided with a useful discharge rate before the dispersals. If the works are done without this checking, the injury to crop breaks out in the much deposited parts, or the supplemental dispersal requires to the control of survivals.

As the results of many investigating data, the boom-type-blow-heads that adoptable to the typical diameter-distribution for the evenness of deposits are guide-molding-type, wall-insert-type, and band-insert-type as in **Fig 7**. And the other, the diameter-distributions that adoptable to the selected blow-heads with the most effective controls for the insects and fungi are 48-250 mesh (mains are 100-200 mesh).

4) Safety from the air pollutions

A remarkable feature of the granule dispersals is the release from the fears of air pollution by the drift of pesticides to the inhabitants. The dusting that blow-in the dust pesticides under 300 mesh into insides of leaves or bottom parts of the stems of crop are more effective than the sprayer and granule-applicator for the vector controls because the defusions and penetrations with the air-blow are sufficient for the deposits to them. But about two-third of the dispersed dust that changes to the drift and others do not deposit onto the surfaces of crops. It is a grave problems for savings of pesticides with the mammalian hazards by drift. And too faithful considerations that the decreasing of the diameters of solid pesticides are more better than the others for the vector controls are not appraisable in recently.

3. Soil-incorporation of granule herbicides

Weed control techniques used the weeder or cultivator mainly were carried out in the upland fields. The soil-incorporation techniques of the granule herbicides are not only dispersed the granules to the surface of the soil, but mixed the granules with soil in a constant depth for the pre-emergence and post-emergence treatments. The incorporation of post-emergence treatment have two control effects that are the chemical and mechanical weeding. In the precedent of designs for the applicators, the granulations of herbicide are inquired into the adaptability to applicators by the members for studying of the applications and granulations. Some of the developed granules have the excessive volatility of technical materials, and the fluidities in pipes and shutter of the applicator are low and irregular (the angles of repose is over 52 degree), so that they cause the uneven deposits on the surface of soil. And when the times from the release in air (enclosed is open) to the dispersal pass over 30 minute by supply, storing, and feeding, the angles of repose change to 32 degree that is high fluidity from 52 degree of the beginning for the volatility of the granules. It was hard problems to keep the constant discharge rate on the discharging system and evenness of deposits.

Thirteen of trial granulations

Fig.8 soil-incorporation of herbicide by tractor-mount-type-granule-applicator

were experienced with angle of repose, absorbability of the technical materials, apparent specific gravity and diameter-distribution. The tested carriers of granule were clay, diatom earth, and pulverized sedimental stone and volcanic ejecta. The kneading or coating that are the containing methods of the technical materials to granules were also carried out to the trials. As the results of this trials, the selected granulation of coating to porous volcanic ejecta is practical to the dispersals for this herbicide and applicator with the values of the angle of repose is 52 degree (48 degree after one hour of the release to the air), the apparent specific gravity is 0.9, diameter-distribution from 24 to 48 mesh is 95% over, and the absorbability is about 7%.

The designs of applicators for this developed granule were laid out with the characters of the applications. For using of the resembled herbicides, the tractor-mount-type-applicator made for trial consist of air-tight tank that capacity is over 100kg, the adjusting and on-off-shutter for the delivering, feeding tubes of granule from the tank to blow-heads, blow-heads which disperse it to the soil surface, and other tubes for the compressed air from the compressor to the shutter that leads the granule to blow-head through the feeding tubes. The granules dispersed on the soil surface are mixed with the soil in the depths of 3-5cm, and sealed into the soil by the tooth and packer setted on the tractor. It is a successful that the feeding system with the compressed air is adapted for the granules of low fluidity, and the incorporation with the soil and granules that dispersed from the hights of 10-20cm with the diffusions by the air-blow, and sealing by the weights of packer can avoid the air pollutions of the drifts for the volatile herbicides.

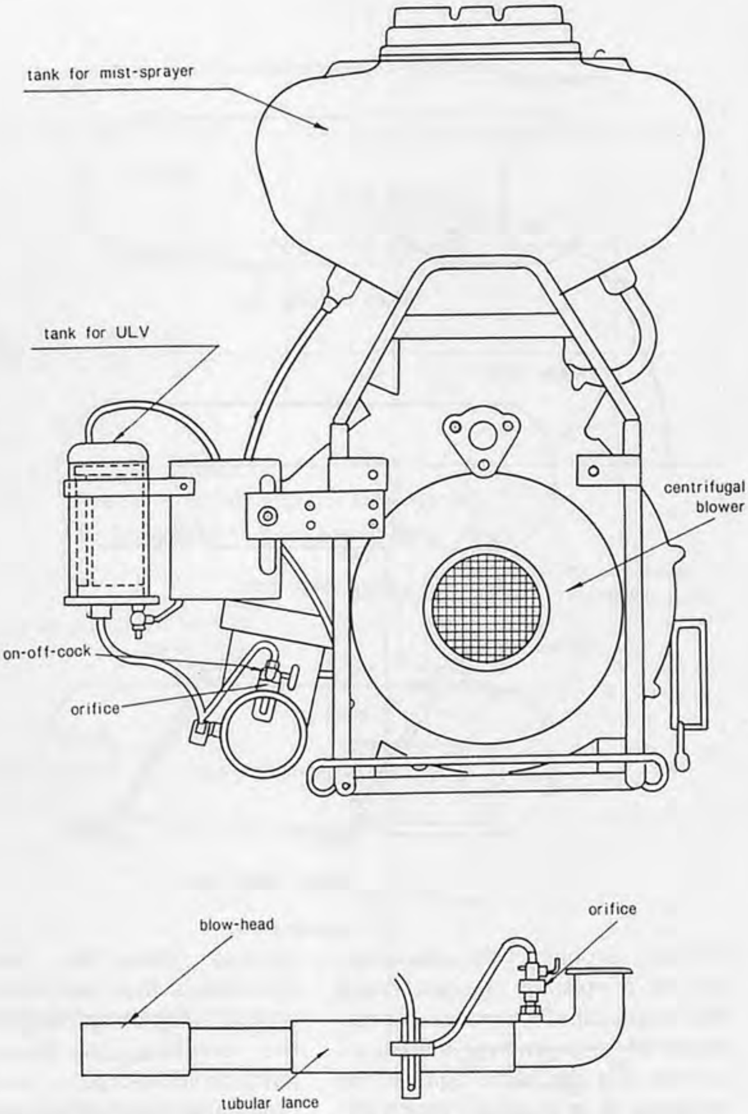

Fig.9 knapsack-type-power ULV sprayer

4. Ultra-low-volume or low-volume-concentrated-sprayer

1) Construction and capacity of ULV sprayer

The developments of ultra-low-volume (ULV) or low-volume-concentrated-sprayer have several potential advantages with the respect to savings in cost and labor by eliminating the water diluent. Knapsack-type-power-sprayer for ULV that can carried on the operator's back are convenient, and tractor-mount-type are also useful for the preventions and exterminations of the vectors on cereal, vegetable crops, ·citrus, and deciduous fruits, etc. The types of this sprayer published since 1967 involve the attachments that mount some assemblies on knapsack-power-applicator, and tractor-mount-power or tractor-trailled-power-applicators. The basic constructions of knapsack as **Fig 9** consist of a two-stroke gasoline engine (30-40cc) that

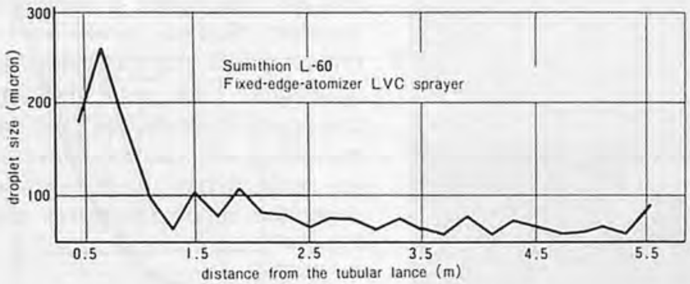

Fig.10 droplet size in the swath width

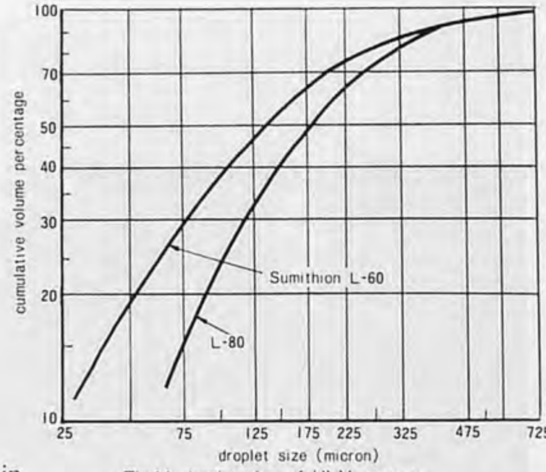

Fig.11 droplet size of ULV sprayer

directly drives a centrifugal blower with the revolutions as high as 7,000 to 7,500 rpm, a liquid tank with the capacity of 400~1,000 ml, and the blow-head or the atomizer situated at the head of tubular lance. The liquid system that leads the liquid of pesticides from the tank to the nozzle setted in head is in the form of a piping system flowing under the gravity in spite of high viscosity. The air in tank maintains low pressure (approximately 150-400 mmAq) due to the blower, and promotes the flow of liquid in the pipe system. The exchangeable orifices in nozzle do the duty for adjusting of the discharge rates in ml/min, and enable choice of the application rates in ml/ha for the dose. Tank, pipe, orifice and on-off-cock are made by the anti-corrosive materials. Tractor-mount-type that is the attachment of tractor as like as boom sprayer, and self-propelled-type that combined with tractor sprayer consist of air-compressor drived by engine, liquid pipes leads the pesticides to the nozzles from the tank, and air-pipes leads the compressed-air to nozzle for the atomizations with air and liquid at each nozzle-holes.

The experimental data that adaptable to the operating of knapsack-type-power ULV sprayer are as follows:

Engine revolution
············7,000-7,500 rpm
Power of engine
············3.0 ps
Flow rate of air
············13-15 m^3/min
Discharge rate of liquid
············5-50 ml/min
Swath width
············4-9 m
Application rate
············1-10 ℓ/ha
Weight of sprayer (empty)
············10-15 kg

In the assumptions of knapsack-power ULV sprayer, areas of spray are 2.5 ha, judicious days are 2 day, workable hours in a day are 4 hr, and number of operator is 1, the capacity of a applicator is about 0.3 ha/hr, and 0.3 ha/hr-man.

The other, the experimental data that for the tractor-mount or self-propelled-type are as follows:

Discharge rate of liquid
············100-500 mℓ/min
Swath width
············4-10 m
Application rate
············2-10 ℓ/ha
Speed of tractor
············2-8 km/hr
Pressure of air
············0.3-0.5 kg/cm^2

Also in the assumptions for the tractor-mount or self-propelled-type, areas of spray are 18 ha, judicious days are 2 day, workable hours in a day are 4 hr, and number of operator is 1, the capacity of applicator is about 3.0 ha/hr, and 3.0/hr-man, because of the times for the supplying of pestcides, the labors for operator or followers and the others are possible to save in the fields.

2) Time-saving for supplying of the pesticides

The total hours of spraying generally are the sum of hours for supply of pesticides, adjusting the discharge rate, transfer from the field to fields, and spray. The capable areas for spraying in a day are given in terms of the working ratio that the spray hours divided by total hours. The researchers of Agricultural Experimental Station reported that a working ratio for ULV sprayer is 85%, and the common power sprayers are less 30%, because of the application rates of ULV are remarkable low. When the application rate is high and tank-capacity mounted on the sprayer is small, the supplyings of the liquid are as much elements of the increase of working hours as that of air-blast-sprayer. If the capacity of tank for ULV is equal to that of a common sprayer, the frequencies of supply to the tank decrease to 1/100 or 1/1,000 in the fields.

3) Droplet size of spraying and control effects of pesticides

Too fine droplets (less 30 micron) cause the excessive drift of the spray to the lee-ward side. The other, too coarse droplets (over 200 micron) decrease the coverage of spray on the leaf and stem of crops. The average droplet sizes for ULV sprayer are from 80 to 140 micron for the successful effects of pesticide and

Fig.12 tractor-mount ULV sprayer in vegetable field

the eliminatings of hazard by drifting. **Fig 10** shows the droplet sizes at locations 0.5 to 5.5 m from the sprayer by using the sheets of red absorbent paper placed horizontally on the short wooden stakes at 0.5 m intervals along a line perpendicular to the base. It is clear that the droplet sizes on the top of swath are more coarse than the end. **Fig 11** shows the cumulative percentages of average sizes of the droplet that are delivered from the blow-head of knapsack-power, the size at 50 % of the cumulative total in Sumithion L-60 (insecticide for ULV) is about 130 micron and the small droplets which cause the drift (less than 30 micron) are under 15 %.

Since 1969, Agricultural Experimental Stations of 12 prefectures in Japan checked the effects of this technique using knapsack-power with 50 formulations of the pesticides for vector control including *Sumithion, Malathion, Depterex, Kasumin,* and others for the extermination of 1st and 2nd inster larva of rice-stem-boror, rice-leaf-hopper, and rice-blast, etc. The control effects of ULV that have insecticidal and fungicidal action were comparatively higher or almost identical with those of the high volume emulation or wettable powder commonly used. *Malathion, Cidial, Sumithion* and others were effective against the some lepidopterous larvae and aphis of cabbage, thrips of onion and others used by the knapsack-power and tractor-mount ULV sprayer as **Fig. 12.** After the harvest in the tea fields, the control effects of ULV formulation of *Cidial* with knapsack-power were successful to small tea-tortrix and smaller green-leaf-hopper of tea.

Horticultural Experimental Stations indicate that the deposits of *Cidial* onto the side and center of citrus tree by the self-propelled-type ULV sprayer as **Fig 13** were comparatively adequate, and the control effects on mealy bug such that reproduction in citrus leaves nearly equalled that of the common techniques. Another Station published the report in 1972 that the deposits of *Sumithion* L-60 onto the apple trees used by same sprayer were exceeding, and the control effects on apple-tortrix were excellent under the application rates are 4 ℓ/ha.

4) Oral, dermal toxicity, drift and residues

The inhalation to mouth and deposition on derma of pesticides are more hazardous problem of this technique for the operators. ULV pesticides should be low toxicity as the values of LD50 for acute toxicity are over 100 mg/kg, and chronic toxicity also should be checked. The researches were carried out into the analysis of inhalation through the mouth and deposition on the cloths of the operator with this sprayer a gas-chromatograph. The inhalation was measured by the content of pesticides on the filter of operator's mask, and the deposits were also measured on papers fixed to the arm and knee while the spraying in area of 0.1 ha. The pesticide used was *Sumithion,* and the application rate was 1 1/ha. The result indicates that the oral and dermal toxicity are not hazardous under this conditions, because

Fig.13 self-propelled-type ULV sprayer in orchard

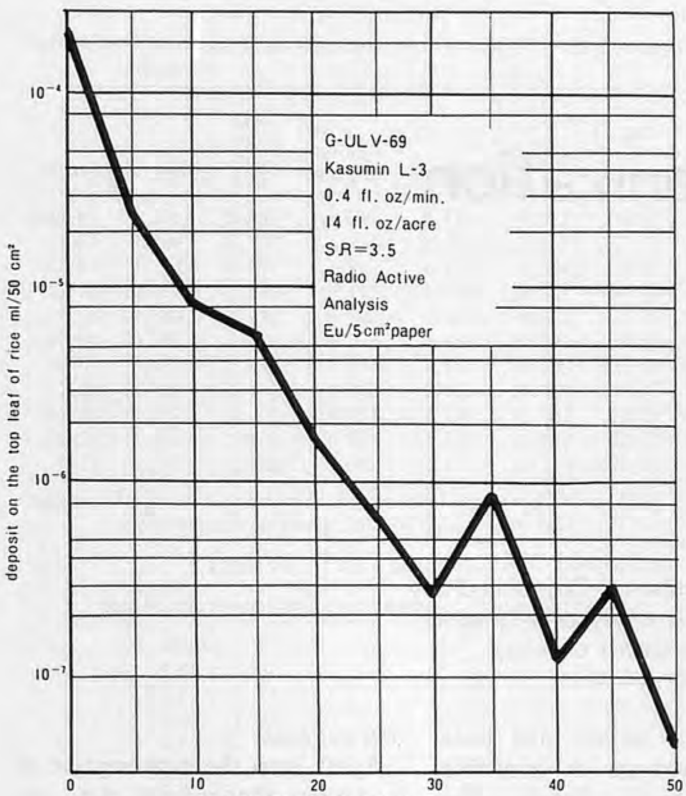

Fig.14 drift by radio-active-analysis

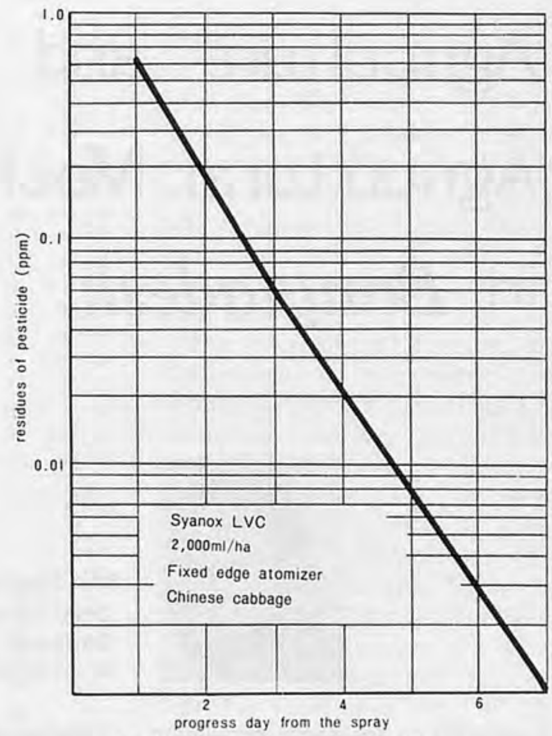

Fig.15 residues of pesticide on cabbage

the LD50 of *Sumithion* is nearly 800 mg/kg.

The drift that causes the hazards of mammalian toxicity due to pesticides should be avoided by the techniques of the spraying. When swinging and sweeping the lance in a variable atmospheric environment, the wind speed and direction, in particular, should be checked before the works are done. The deposits at points of 5 m intervals from the end of the swath to the lee-ward side after the spray for the check of drift were measured by Radio-Active-Analysis-Method in co-operation with Radio Isotope Center of Japan. As the results of this analysis, the distance by which a deposit decreases to 1/100 of the end of swath was 30 or 40 m on the lee-ward side, under the conditions that the lance hold at 3-4 degree above the horizontal, swath width is 4 m swinging from left to right, wind velocity is 1 or 2 m/sec, and temperature is 20°C in the fields as **Fig 14.**

The residues of pesticide in the products at the harvest should be checked against the tolerance for safety in the human diet. The gas-chromatographic technique was employed for the analysis of the deposited insecticides on the leaves of chinese-cabbage sampled. Used pesticide was *Syanox* formulated to ULV for the control of aphis and beet worm on the cabbage. The result indicates that the residues decrease on a logarithmic scale with the passages of time, and attain to the permitted level of toxicity after one week as **Fig 15.** ■ ■

Agriculture and Agricultural Mechanization in *Bangladesh*

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I. Agricultural geography, population, arable land, annual production and per capita income.

Bangladesh, a newly born country in the world map from 16th December, 1971, is situated between the latitudes of 21°N and 27°N and longitudes 88°E and 93°E. The country is regarded as the largest deltaic formation at the confluence of three mighty rivers--the Ganges, the Brahmaputra and the Meghna. More than one-third of her area lies directly within the tropics, and the rest within mild temperate zone. The Bay of Bengal which occupies the entire southern boundary together with the monsoon have made the country suitable for luxuriant growth of green vegetation. Geographically known as the Bengal basin, the country has a total area of 55,126 square miles of which the net area planted to crops is 22.32 million acres, **Table I.**

The present population of Bangladesh is 75 million which is increasing at an annual growth rate of 3 percent. By 1979-80, the population will be 92.25 million. Thus the population pressure in Bangladesh is servere and little additional acreage is available for cultivation. People are cramped, perforce, into the cultivable areas, with one square mile of agricultural land for more than 2,100 persons. Bangladesh'es major problem is hunger, the hunger of a large proportion of tremendous and rapidly increasing population, **Table II.** The present shortage of foodgrains is 3.0 million tons.

The total production increased from 9.551 million tons in 1960-61 to 11.077 million tons in 1970-71 and the availability of foodgrains (including imports) rose from 9.312 million tons in 1960-61 to 11.114 million tons in 1970-71. This small increase in production could not cope with the population increase.

Apart from the consumption of foodgrains the general diets are very much imbalanced and still remain at relatively low levels. The gap in dietary level seems to be widening overtime principally because the population growth has absorbed most of the annual output.

It is, therefore, essential that the full limit of production be wrung from every available acre. And so far as their situation, ability, and equipment permit, Bangali farmers as individuals strive toward this goal. They farm in areas where hazards of alternating flood, drought, and salinity from sea water are frequent occurrences. They try to make inter cropping and double

Table I. Land utilization pattern in Bangladesh.

Description	Amount (Million Acres)	Percentage
Total land	35.28	100.00
Forests	5.40	15.26
Culturable waste	1.26	3,55
Not available (Houses, Rivers etc.)	6.30	17.87
Total land not available for cultivation	12.96	36.68
〃 〃 available for cultivation (cropped area)	22.32	63.32
More than once cropped area	10.00	
Crop intensity	–	144.80

Table II. Population, production and availability of foodgrains in Bangladesh.

Year	Production	Less seeds etc. 10%	Net available (Domestic)	Imports	Total available for consumption	Population (million)	Per capita /day ounces	Index
1960-61	9.551	0.955	8.596	0.716	9.312	55.57	16.40	100.00
61-62	9.504	0.950	8.554	0.400	8.954	57.29	15.32	93.40
62-63	8.774	0.877	7.897	1.437	9.334	59.07	15.42	94.02
63-64	10.490	1.049	9.441	1.006	10.447	60.70	16.80	102.43
64-65	10.380	1.038	9.342	0.355	9.687	62.79	15.22	92.80
65-66	10.369	1.037	9.332	0.888	10.220	64.61	15.52	94.70
66-67	9.482	0.948	8.534	1.164	9.698	66.48	14.34	87.44
67-68	11.053	1.105	9.948	1.021	10.969	68.41	15.71	95.79
68-69	11.257	1.126	10.131	1.120	11.152	70.39	15.62	95.24
69-70	11.920	1.192	10.728	1.540	12.268	72.43	16.59	101.15
70-71	11.077	1.108	9.969	1.450	11.114	75.01	14.53	88.60

Source—Ministry of Agriculture, Agricultural Production Plan (1972-77) and Food Self-sufficiency programme (1974-75) Dacca, May 1972.

Table III. Farm Size pattern of Bangladesh

Size of Farms (Acres)	Number of farms (million)	Percentage
Below 1.00	1.10	17.00
1.00 —2.50	1.75	26.60
2.51 —5.00	1.76	26.80
5.01 —7.50	0.83	12.60
7.51—12.50	0.64	9.70
12.51—25.00	0.31	5.60
25.01—50.00	0.09	1.40
over 50.00	0.02	0.30
Total	6.50	100.00

cropping wherever the seasons permit. In some parts even three crops are grown annually yet the per acre production of crops is very low. The farmers are expert in their premitive method of agriculture but suddenly they have become outdated for increasing population pressure and demand of more agricultural products per acre and per man which is possible only through modern scientific and technological methods.

The principal crops in Bangladesh are rice, jute and sugarcane. Oil seeds, tea, tobacco, potato, wheat and cotton are also produced in some parts of the country. Other than those, several varieties of fruits and vegetables are also produced. Bangladesh leads the world's production of jute with an annual production of more than 7 million bales (400 lbs. each bale). Production of other agricultural products is low, however, Bangladesh is fifth in the world production of rice having a production of 11.01 million tons as in 1970-71.

The agricultural land of Bangladesh is divided into small subdivisions and fragmentation among 6.50 million holdings giving an average of 3.5 acres per family, **Table III.** But per capita acreage of cultivated land for the total population of Bangladesh is less than one-third acre.

Bangladesh is solely dependent on her agricultural resources for her social, economic, industrial and overall development. The economy of Bangladesh is dependent on agriculture. About 85 percent of total population depends on agriculture for their livelihood. At 1959-60 factor cost, the share of agriculture in the gross domestic product (GDP) in 1959-60 was 62.2% but in 1969-70 was only 55%. The contribution of manufacturing sector including both large and small scale manufacturing units was 6.0% in 1959-60, 6.5% in 1964-65 and only 8.7% in 1969-70.

The agricultural sector of Bangladesh is responsible for earning 75 percent of foreign exchange by exporting jute and jute products, tea, skin, and other agricultural products. The average per capita income is Taka 450.00 (about US$90.00) but the per capita income of a farmer is far less, about Taka 190.00 (about US$40.00). The farmers are poor, illiterate, underfed and agriculture for them is a way of life rather than a business since they have no capital and have no other alternative choice of livelihood.

2. Agricultural patterns and regions of Bangladesh.

Excluding the Chittagong Hills and the Sunderban coastal forests in the Bay of Bengal, there is a general similarity in the cropping pattern throughout Bangladesh. The region is a lowland plain built mainly by the delta-forming activity of the Ganges, the Brahmaputra and the Meghna, and is covered with countless swamps. The climate is tropical and humid, and has heavy rainfall, which is highly seasonal. Average annual rainfall is about

Table IV. Contribution of agriculture to G.D.P. of Bangladesh at constant factor cost of 1959-60 (ten million taka)

Year	GDP	Agriculture		Year	GDP	Agriculture	
		Account	Percent			Account	percent
1959-60	1448.9	904.2	62.4	1965-66	1856.9	1075.7	52.4
1960-61	1531.0	959.0	62.6	1966-67	1875.4	1046.7	55.9
1961-62	1620.6	1001.2	61.8	1967-68	2034.6	1154.2	56.7
1962-63	1613.0	967.5	60.0	1968-69	2124.9	1180.3	55.5
1963-64	1785.5	1059.8	59.3	1969-70	2231.7	1234.4	55.3
1964-65	1796.5	1048.5	58.3				

Source: Economic Survey of Bangladesh (the then East Pakistan) —1969—70.

76 inches, with extermes of from about 53 inches in Rajshahi district to about 226 inches in Sylhet district, 85 percent of the rainfall occurs during the five months from May to September — the Monsoon period. Except for the eastern districts, which are not subject to flooding, the country comprises flood plains and delta of the three rivers. The country slopes gently towards the sea and most of the area is less than 50 feet above sea level. The land to the west of the Brahmaputra is relatively high, but in the east falls away into a depressions--the 'beel' and 'haor' areas--in the districts of Mymensingh and Sylhet.

The soil is very fertile and of sedimentary type since it has been formed by the deposits brought down by the rivers. As is customary with such alluvial soils, the texture is lighter in the upper reaches of the rivers. High rainfall has leached the soil and the traces of salts, mostly chlorides and sulphates of sodium, calcium and magnesium, ordinarily present in alluvial soils have been washed away. Generally the reaction of the soil is acidic and the pH value varies from 6.0 to 7.0.

Topography and precipitation have determined the agricultural pattern. In the highlands of Comilla, Chittagong, and Chittagong Hill Tracts, not subject to flooding, jute or rice is grown only in the rainly season. During the dry season a small area is cropped under rabi crops, such as pulses. Failure of the monsoon occasionally results in famine conditions over vast areas. Irrigation can insure against drought and possible double and even triple cropping.

The flood plains of the rivers remain under water during the high floods, and are not avilable for cultivatiion at that time. Rice is, however, grown when the water recedes. But if, as frequently happens, the flood is excessive or occurs at an unusual time, or does not recede sufficiently at the time of transplantation of rice, crop failure results. Flood regulation, irrigation by gravity and surface pumping can greatly alleviate this situation. The major portion of the haor areas in the Sylhet and Mymensingh districts remains underwater throughout the monsoon season and is dry during winter. Boro (winter) rice is grown in areas that retain moisture from the monsoon flooding. Such areas, however, form a very small portion of the total. Pump irrigation offers considerable opportunity for developing these areas, where at present the main occupation is fishing. Large tracts of beel areas in Faridpur, Khulna, Tippera, Sylhet, Mymensingh, Rajshahi, Pabna, Bogra and some other districts, remain under water for most part of the year. These areas can be drained and brought under cultivation. With protective embankments and irrigation, the coastal areas, which are subject to intrusion of saline sea water, can support intensified and diversified cropping, where at present rice is grown mostly.

3. Agricultural Development and Mechanization in Bangladesh.

From time immemorial the agricultural sector of Bangladesh suffered a gross neglect. No plan for agricultural development was taken by any agency, government or private. However, with the establishment of the Planning Board in 1953 (in the then East Pakistan), a systematic approach for the development of agriculture including agricultural mechanization was initiated. The plan provided Taka 23.40 million for agricultural development. During 1959-60, the government gave 1150 pumps and 47,000 acres were brought under irrigation, 346,000 acres were covered with plant protection measures and 7,000 acres waste land was developed.

During the period from 1965 to 1970, the use of machine was increased, 2,238 power pumps were provided, 131,000 acres were irrigated, 200 tractors were imported, 13,828 hand sprayers, power sprayers and dusters were distributed and two workshops were established.

During the period from 1965-70 agricultural mechanization progressed further. The number of tractors increased to 2,072 and the number of power tillers introduced was 2,571 power pumps were introduced -- 18,603, and 1,230 tube-wells were installed. The actual expenditure on various programmes in the public sector was estimated to be 351.31 million taka.

The year 1971 was a period of war of liberation for Bangladesh. After liberation, the government of the People Republic of Bangladesh has given a greater priority to agriculture sector and allocated Taka 1541.40 million for agricultural programme out of its total budget of Taka 5100.00 million in 1972-73 even after allocation of a huge amount for reconstruction and rehabilitation programmes.

(i) Farm Power in Bangladesh.

The available agricultural power in Bangladesh is from work animals and human beings. There were about 23 million work animals in 1970-71 of which cattle were 96 percent, buffaloes three percent and horse one percent. The work animals of Bangladesh are small, underfed, and in the present competition between man and animal for food and feed, their condition represents a constant anxiety to the farmer. Their poor condition precludes the use of improved implements and this, in turn, necessitates ploughing the land a very large number of times even after which the land cannot be brought into satisfactory condi-

Table V. Distribution of Tractors in Bangladesh, 1970.

Sectors		Number of tractors
1. Private		1,657
2. Public Agencies*		
(i) BADC	257	
(ii) BIDC	111	
(iii) BWAPDA	14	415
(iv) Agri. Deptt.	16	
(v) BARD (Comilla)	17	
		Total 2,072

*BADC— Bangladesh Agricultural Development Corporation
BIDC— Bangladesh Industrial Development Corporation.
BWAPDA—Bangladesh Water & Power Development Authority.
BARD— Bangladesh Academy of Rural Development.

Table VII. Horse power distribution of Tractors of Bangladesh.

Hp range	Number	Percentage
Upto 25	8	Less than 0.5
26 to 35	144	7
36 to 45	1,108	53
46 to 55	696	34
56 to 66	40	2
over 66	76	4
	2,072	100

Table VI. Different Makes of Tractors in Bangladesh

Company		Number of Tractors
Massey Ferguson	—	1,180
International	—	245
John Deer Lang		54
Belanes	—	362
Duetz	—	100
Romanian I.H.I. 533	—	60
Others	—	71
		Total 2,072

Table VIII. Average operating period of Tractors (hours/tractor) in Bangladesh by Different Agencies.

Agency	April to June	July to September	October to December	January to March	Total/year
BADC	50	—	100	300	450
BIDC	304	216	395	425	1,341
BWAPDA	53	4	18	257	332
BARD	280	224	227	371	1,102
Private (Average)	—	—	—	—	1,400

tion.

The situation has aggravated further due to severe losses of cattle by devastating natural calamities such as floods, cylones, tidal bores, etc. Besides, the occupation army of Pakistan destroyed about 2.6 million work animals. At present, there is a tremendous shortage of work animals. The situation, as it prevails today, is critical. Large tracts of Aus area remained fallow in 1972 for want of drought animals. Attempts were made to procure bullocks from India. But it was difficult to procure such a large number of bullocks due to difficulties in movement and transportation. Moreover, bullocks are subject to changes in climate and weather. Breeding and production of bullocks can be considered, but the loss sustained by now cannot be recovered in the immediate future. Land cannot be allowed to remain fallow, machine power has to be employed in order to accelerate the agricultural production since Bangladesh already faces an annual shortage of food-grain to the extent of 3.0 million tons.

There may be as many as 35 percent of farmers who do not have any work animals. The traditional defect in farming may be due to poor quality of work animals which possess an energy equivalent of less than one-fourth H. P. per head. The use of work animals causes shallow ploughing, inadequate pulvarization and laddering and loss of time due to requirement of large number of operations. All these factors lead to less production per acre. Tractor cultivation in India has increased the crop intensity by 20 percent with 22 percent lower cost having increasing the yield from 16 to 33 percent.

The number of tractors in Bangladesh upto June, 1970, was 2027 of which 40 were crawler type and the rest wheel type. In the public sector, there were 415 tractors, while in the private sector the figure was 1,657, **Table V**. The tractors in the public sector suffered from misuse and improper maintenance and only 60 percent were in working condition while those of private sector were good and 75 percent were in working condition.

The tractors of the private sectors were owners of farm land of 20 acres, or more. Fifteen percent of these tractors were with owners of the farm of 100 acres while 13 percent were with owners having farm area less than 25 acres. Many of the tractors were used for haulage rather than tillage. Considering economic limitations and farm size, power tillers were introduced in Bangladesh. By the end of June, 1970, 3,614 power tillers were imported of which 2,571 were distributed, out of these 1,816 had been distributed on loan from Agricultural Development Bank of Bangladesh. The rest of the power tillers 755 in number (28 percent) were purchased by the farmers with their own cash or cash borrowed from sources other than ADBB.

The operation of power tillers and tractors was scattered all over the country and the thus has not proved to be successful. There have been frequent cases of breakdown of tillers which could not be repaired very soon or at all due to one or more of the following factors: (i) non-availability of spare parts, (ii) inadequate servicing facilities, (iii) short of technical personnel, (iv)

Laying precast concrete channel sections for the efficient distribution of irrigation water on the farm.

difficulties in transportation, (v) non-availability of workshop facilities. Many a times, power tillers and tractors were inoperative due to shortage of fuel and lubricant. As a result, the efficiency in operation has been very low, and tractor/tiller became a burden for the farmer instead of helping him. In the cyclone affected areas a fleet of tractors and power tillers (162 tractors and 569 power tillers) which were so long operated on isolated basis, were being operated in a concentrated manner. The area coverage under these tractors and power tillers were lower than the rated capacity. A number of problems were experienced in successful operation of these tractors and power tillers even in the concentrated area: (i) Tractor and Power tiller operation being a complicated task the drivers and mechanics could not be trained until 2 to 4 years of their training, (ii) there should be a network of workshop facilities, (iii) without reasonable efficiency the operation of the tractors and power tillers become uneconomic, (iv) although the size of the holding may justify more use of power tillers than tractors, the operating cost of a power tiller per acre is much higher than a tractor since capital cost per acre and servicing and maintenance cost per acre are much higher for power tillers than those for tractors. Without proper planning and organizational base, the operation of tractors and power tillers become prohibitive.

(ii) Irrigation in Bangladesh.

Bangladesh is laced, as already mentioned, with a dense network of water courses branching out of the three principal river -- the Ganges, the Brahmaputra and the Meghna. A rough estimate gives a figure of 925 million cubic feet of water annually brought by these rivers. These water courses provide about 2700 miles of naviagable channels open during the monsoon, and about 1,800 miles open during the dry season. These water courses could provide irrigation water during dry season if pumping equipments were available, thus enabling a second or even third crop to be grown in the greater part of the country.

During the monsoon, flood plains of the rivers are inundated and when the flood recedes a large volume of water is retained in innumerable inland water reservoirs, such as swamps, 'beels' and 'haors', with which the whole countryside is interspersed. Most parts of Mymensingh and Sylhet districts and the western parts of Comilla districts are covered with the swamps.

These, combined with heavy rainfall, mean that Bangladesh has plently of water resources and there should not be any reason for the crops to suffer for want of water. It has already been stated that most of the rainfall occurs during the five months from May to October resulting in Two well defined seasons: -- wet season and dry season. In the wet season 70 percent of flat land is inundated and the only crops that can be grown are rice and jute. In the dry season only a small part of the land is put under a second crop due to non-availability of irrigation water.

The wet season rice crop is 'aus' and 'aman' and their yield depends to a large extent on timely rainfall. Pre-monsoon showers are necessary for 'aus' crops and late monsoon showers are necessary for 'aman' crop. Failure of these, early floods, sudden rises in the flood level, late floods, and too early a cessa-

Table IX. Imports and Distribution of Power Tillers in Bangladesh upto June, 1970.

Make	Year						Imported	Distributed
	1965	1966	1967	1968	1969	1970		
Iseki	50	15	217	117	195	—	594	426
Kubota	50	100	142	223	301	—	816	601
Mitsubishi	128	105	184	192	333	—	942	609
Satoh	50	96	—	—	96	70	312	199
Yanmar	50	395	—	127	278	100	950	736
Total	328	611	543	659	1,203	170	3,614	2,571

tion of rains in the late monsoon, and the lack of irrigation water are the limiting factors of production.

In Bangladesh more than 60 percent of the land area is under cultivation and so the scope for extending cultivable land is limited. Only possible land reclamation is by irrigation of the northern districts and the coastal belts which are subject to inundation. Irrigation is essential to increase output per acre of lands, already under cultivation.

About1.26 million acres of land area of Bangladesh are classified as culturable wastes. Mechanized cultivation coupled with irrigation and drainage, could bring a substantial part of this area under the plough. These improvements can make the total cultivable land to 23.58 million acres from the present 22.32 million acres.

Thus irrigation and flood control can substantially increase the production by bringing more land under cultivation, by introducing double and tripple cropping, by preventing saline ingression of coastal areas, and by ensuring the supply of water in time of shortage.

Irrigation in Bangladesh can be done in a whole variety of ways, ranging from power pumps, deep tube-wells and shallow wells, tanks and minor irrigation and drainage schemes to several major canalization projects. Thus, its potential extends over a very large part of the country.

(iii) Power pump and tube-wells for irrigation.

The use of power pump and tube-wells for irrigation specially in the winter season is considered to be one of the most important steps towards increasing production per acre. Since the winter season is dry, the cropping during this season depends on artificial irrigation. The use of irrigation water also facilitates applications of higher doses of fertilizers. By the end of June, 1970, 18,603 power pumps were distributed and 1,230 deep tube-wells were installed, out of these 18,125 power pumps and 790 deep tube-wells were in operation.

The overall irrigation facilities in Bangladesh are limited. The Thana Irrigation Project (TIP) with the help of BADC has distributed 24,483 power pumps for estimated irrigation of 1,055,930 acres upto June, 1972. The programme for TIP for 1972-73 is the use of 35,000 power pumps with a total cusec capacity of 56,425 and for a total irrigated area of 1.13 million acres on the assumption that per cusec coverage will be 20 acres. Under the tube-wells programme BADC will sink 2400 deep tube-wells and 4,000 shallow wells in 1972-73. By the end of June, 1972, 979 deep tube-wells were commissioned covering an area of 34,500 acres. Out of the new tube-wells which will be sunk, almost all will be operational during the next year. An additional 143,000 acres are expected to be covered next year. In Bangladesh, at present there are 1007 shallow tube-wells covering a total area of 7,049 acres. There is a programme for sinking of 4,000 shallow tube-wells for 1972-73. If implemented, the 4000 shallow tube-wells will provide irrigation to an additional area of 28,000 acres. All these power pumps and tube-wells will provide irrigation to 1.343 million acres by 1972-73.

(iv) Irrigation projects of BWAPDA.

The Bangladesh Water and Power Development Authority (BWAPDA) has so far completed 5 multipurpose-flood control-cum-irrigation projects. The BWAPDA has been divided into two boards: (i) Bangladesh Water Development Board, BWDB and (ii) Bangladesh power development Board, BPDB, after liberation. The BWDB has 7 more irrigation projects which are in hand. By the end of 1972-73, all these irrigation projects will provide irrigation facilities to 1,657 million acres and with the BADC and TIP project, total acreage under irrigation will be 3 million acres.

(v) Sprayers and dusters for plant protection.

As already mentioned there has been quite a good progress for mechanization of spraying and dusting by introducing 13,828 power sprayers, hand sprayers and dusters by 1960. Today the country has 38,000 hand sprayers and dusters and about 15,000

Table X. Distribution of power pumps and tube-wells in Bangladesh upto June, 1970.

Agency	No. of power pumps		No. of tube-wells	
	Installed	Working	Installed	Working
BADC	17,844	17,844	650	320
BIDC	54	29	25	20
BWAPDA	594	185	370	322
Agri. Deptt.	1	—	5	2
BARD	110	67	180	126
Total	18,603	18,125	1,230	790

Table XI. Operating period (hours) of power pumps in Bangladesh (1969-70)

Agency	April to June	July to September	October to December	January to March	Total
BADC	125	25	50	200	400
BIDC	346	72	60	547	1,025
BARD	499	—	—	524	1,023
Agri. Deptt.	—	—	—	—	—
Overall average	126	26	50	201	403

power sprayers. The government plan is to introduce 125,000 sprayers (hand sprayers equivalent) in 1972-73 for covering 136, 150 spray acres which will spray 17,606 tons of pesticides. A recent survey conducted by the Farm Power and Machinery Deptt. of the Bangladesh Agricultural University indicated that 44 percent of the farmers of Bangladesh want one or other kind of sprayers for plant protection. Thus there is a demand for mechanization of plant protection operations.

(vi) Minor implements and tools.

The farmers of Bangladesh use hand tools and implements for all kinds of farm operations. They need plow, rake, sickle, nirani, etc. Of the 6.5 million farm families 6.0 million farm families have all kinds of hand tools for farm. For 25 percent replacemet of these we need 1.5 million of each of these tools each year. In addition to these, farmers are now using seed drills, threshers (Paddle and power), etc. The exact number of these equipments are not available. However, for line sowing of jute cultivation 25,000 seed drills are necessary by 1974-75. An agricultural development plan (1972-77) by the Ministry of Agriculture, estimated the requirement of tools and implements to following numbers:

Sprayers -	125,000
Paddle Threshers	25,000
Power 〃	2,500
Small Dryers	800
Seed Drills	25,000

(vii) Agricultural Development Agencies of Bangladesh

The government of the Peoples Republic of Bangladesh has placed priorities for overall agricultural development of the country and has set up several organizations for tackling various aspects of agricultural sector.

At present there are a total of 31 agencies which are engaged in agricultural development of Bangladesh. All these agencies are distributed under eleven ministries of the government. These are the following:

1. Ministry of Agriculture: (i) Agricultural Extension and Management Directorate, (ii) Agricultural Research and Training Directorate, (iii) Agricultural Marketing Directorate, (iv) Agricultural Information center, (v) Jute Research Institute, (vi) Credit Research Institute, (vii) Soil Survey Project, (viii) Plant Protection Project, (ix) Silos Project, and (x) Agricultural Development Corporation.

2. Ministry of Forestry, Fisheries and Livestock Services: (i) Veterinary Service Directorate, (ii) Directorate of Fisheries, (iii) Directorate of Forestry, and (iv) Fisheries Development Corporation.

3. Ministry of Flood Control and Water Resources: (i) Irrigation Directorate, (ii) Land and Water Use Directorate (BWAPDA), and (iii) Water Development Board (BWAPDA).

4. Ministry of Rural Development and Co-operatives: (i) Cooperative Directorate, (ii) Integrated Rural Development Board, (iii) Bangladesh Academy for Rural Development.

5. Industries Ministry: (i) Sugar Board, (ii) Forest Development Board, (iii) Silk culture Directorate (Bangladesh Industrial Development Corporation).

6. Finance Ministry. (i) Agricultural Development Bank.

7. Commerce Ministry: (i) Tea Board, and (ii) Jute Marketing Corporation.

8. Scientific Research and Natural Research Ministry: (i) Agricultural Research Section (Atomic Energy Centre), (ii) Food Technology Section (Scientific and Industrial Research Council).

9. Education Ministry: Bangladesh Agricultural University.

10. Land Reclamation and Land Revenue Ministry: (i) Land distribution rehabilitation and development department.

11. Planning Ministry: (i) Agricultural Division of the Planning Commission.

All these agencies have specific responsibilities for development of different aspects of agriculture. In many cases, the different works of the different agencies overlap each other. Many a times, there is no coordination and cooperation, between the different agencies rather common interests create clashes between some of the agencies. In addition, repetition and duplication of many works occur frequently. All these agencies employ several kinds of personnels having several kinds of qualifications and several positions. But actual services the farmers get are from those who are not educated properly in agriculture. There are no subject matter specialist who serves the farmers directly. As a result, the agricultural development is suffering from inefficient management, administration and planning. Government should reorganize the whole system for better administration and management.

4. Steps required for modernization and mechanization of agriculture.

Bangladesh is seriously deficient in food. With 22.32 million acres of cultivable land, she can not feed her 75 million people while Japan with less acreage per person produces surplus food for her people. Increasing the per acre production of agricultural products is the only way for attending of the shortage of food and reaching self-sufficiency within a reasonable period of of time. The modernization and mechnization of agriculture is the only solution for increasing per acre production. A Programme for modernization and mechanization of agriculture is necessary for achieving such a goal. There is also necessity of proper planning of the programme to assure that all necessary elements are properly phased into the programme. A balanced national development planning is indispensable for Bangladesh. Since agriculture is a way life for 85 percent of her population, agricultural problems should not be considered separately from other basic problems like population growth check, removal of illiteracy, provision of proper shelter, health service improvement, movement, transportation, marketing problems, etc. which are directly related to each individuals daily life.

(i) Education of farmers

There are, of course, many factors impeding the development of Bangladesh economy, but the foremost among them is the general illiteracy which distinguished our country from all other civilized countries of the world. An increase of labour productivity is the only means to erase poverty in Bangladesh and the best policy to achieve it is through the spread of education and knowledge. There are three levels of areas for education which affect the agricultural progress:

1. The farmers
2. Those serving the farmers directly or indirectly
3. Those leading the farmers and or are making policies which affect farmers.

Farmers are the central catalyst in the process of agricultural production. He manipulates plants, animals, tools and implements and takes all the decisions in the productive process. Hence, the agricultural growth of Bangladesh will result from the individual changes of millions of our farmers and their farms. Modern farming is an economic activity which involves knowledge on the part of the farmer, skill in applying his knowledge, the will to apply the knowledge and the physical ability to execute this knowledge and carry on the activity. Agricultural growth occurs as the result of changes in these areas, changes which come largely through education or a 'perceived experience which leads to a change in future behaviour patterns'. Therefore, the fundamental problem of agricultural growth of Bangladesh is the educational problem. Though there is a limited evidence which indicates that education plays a role, the impact of education is conceived only after the period of take-off. Developmental education with emphasis upon extension education methods seem to have the greatest role to play in our agricultural growth at this stage. Three kinds of developmental knowledge are required:

1. Knowledge about new inputs which may be made available and which in fact produce favourable results; new seeds, varieties, fertilizers, pesticides, sprays, breeds of animals, animal feeds, farm-implements and equipment (mobile and immobile). Our farmers also need new knowledge about food inputs which will improve the nutritional level of the farm family and its labour forces as a preventive health measures.

2. Knowledge about new techniques of production: time and technique of planting, time of irrigation, maturation and protection of crop or animal. (Weeding, spraying, fertilizing plus timing and rate of application), harvesting, cutting, weaning, feeding etc.

3. Knowledge about how to economize in production and marketing (i. e. the farmer's net return or maximum output for minimum cost): Our farmers require knowledge about the optimal combinations of factor inputs and the optimal combination of output mix since many of our farmers have multi-product farm. This is very much essential for economic farming in our country. In marketing, our farmers need knowledge about new or improved techniques of marketing such as when to sell, how to prepare for market (grading, quality control, processing, packing, storing, transportation) and how to secure accurate price information for best economic gain).

(ii) Research needs:

In Bangladesh the extension education, community development and related programmes will continue for quite sometime to bear the brunt of transmitting new knowledge to the farmers. The three kinds of knowledge mentioned above must be gained by adaptive research which are particularly suitable for Bangladesh. Since there is no universal production techniques or inputs which are equally suitable for all countries, the techniques and inputs of production developed for advanced countries cannot be directly applied for Bangladesh. Therefore, the second requirement for agricultural growth of Bangladesh is making of a programme for adaptive research using as much information as possible from other countries. This adaptive research programme can be related to the extension programme to farmers.

(iii) Production inputs.

Transmitting knowledge about new inputs of production to the farmers would mean nothing if the farmers are not supplied with these inputs adequately and timely. Therefore, the third requirement for agricultural growth of Bangladesh is establishment of physical facilities for adequate and timely supply of new inputs. Each of the new inputs should be nearest to the doors to the farmers whenever they need them. Perhaps, this requirement demands a huge expenditure on the part of the government.

For input of new seeds (better variety seeds), more seed multiplication farms as are now existing for BADC may be established. The seeds must be scientifically preserved. At the initial stage some imports as has already been done may be necessary but we should have enough farms to cope with all the requirements. The BADC or government should continue to subsidize the supply of seeds for another 5 to 10 years.

For fertilizers input, Bangladesh has the following factories with their installed capacities:

Factory	Capacity (tons)
1. Ghorashal Urea factory	340,000
2. Chittagong TSP "	155,000
3. Fenchuganj Urea "	106,000

In addition to these there are a few more projected factories by BIDC. All these factories when completed will not only reduce our current heavy dependence on external assistance but may even have some potential for export to India which currently has a large unsatisfied demand for fertilizer. We need to establish some factories for MP fertilizer. The price of fertilizer has recently been increased a little in order to check smuggling of the fertilizer across the border.. However, there is a huge shortage of fertilizer at the 'aman' season of 1972. This situation is expected to be better during the next year.

The input for pesticide and insecticide is presently met by imports. There are two formulating plants--M/S. Insecticides Enterprise, Dacca, and Agrochemicals Ltd., Chittagong with formulating capacity of 378,000 IG and 287,000 IG of liquid pesticides only, respectively. The latter can also formulate dust and wettable powder and can formulate granules with local carrier. Two projects are under negotiation by the government I. P. S.-Cynamide Project- to manufacture Malathion, Accothion, and Thimet granules and CIBA-BIDC Project to manufacture Dimecron. Carbicron and Nogos. The government is distributing pesticides free of cost to the farmers in view of a large expansion of acreage under new varieties. For 1972-73, pesticides import requirement is 12000 tons of which granular pesticides will be 6,000 tons. We cannot continue to import pesticides and give free to the farmers. We need to expedite the negotiations of the above projects which will have such capacities that the country is self-sufficient for pesticides input supply.

The next input requirement for increasing crop production is farm implements and equipments (both mobile and immobile). Here, Bangladesh is lagging far behind. With the inputs of new seeds and varieties the requirements for irrigation and drainage (water management and control), fertilizers and pesticides increases tremendously. The aspects of irrigation has been dealt with separately. The Bangladesh Water Development Board, recently established by the government shall take care of input of irrigation water but a few points are to be considered while going for new projects in view of the experience gained from G. K. Project and others. In these projects the main emphasis has been on the engineering side of making convayance systems or canals and very little work has been done on the satisfactory preparation of land, managment of water use and the education of farmers to receive and use the water to the best advantage. This became conspicuous in the first major projects which came into action in 1960, the Ganges Kobadak (G. K.) Project with irrigation capacity of 150,000 acres. Due to ineffective systems of field channels to distribute water evenly it was found near Bheramara Power Station that some places were dry while other places were flooded when water was applied directly from a main channel. Agricultural engineers come into the picture to make the end-use satisfactory which is the objective of such irrigation projects. They are the best suited personnel for getting the land properly levelled and getting the water courses laid out in the most economical and efficient manner for distribution and easy maintenance. Making of field channels sacrificing crop land is a national loss for Bangladesh. As such we should not go any further for such big canalized projects rather projects should be undertaken which make use of sub-surface irrigation system so that our costly cultivable land is not wasted any more.

With the availability of irrigation water for a sizeable portion of our cultivable land and with new seeds, fertilizers, and pesticides, the cropping intensity in these areas can be increased to even more than 300 percent by mechanization of agriculture. At the end of 1972-73 session about 3 million acres will be brought under irrigation, if a tractor can cultivate 1,000 acres per year 3,000 tractors are necessary for this area only. In addition to these, planters, seed drills, fertilizer distributors, sprayers, etc. are necessary for seeds, fertilizers, pesticides, etc. in appropriate amount, time, and doses, for best utilization. If the crops can be planted and harvested quickly by mechanical means only then multiple cropping is feasible. With mechanization of production and drying of grains the potential multiple agricultural production is realized. Therefore, mechanization of agriculture is the next requirement for agricultural growth of Bangladesh.

Mechanization cannot emerge alone. Complimenting factors must be evolved and developed in balance with mechanization. With the use of new inputs for production, the cost of production increases, so greater production is necessary for an adequate economic return. Therefore, it is essential that the total production system be analysed and considered and all production inputs be increased in proper balance. Farm implements and equipments as production inputs should be increased along with other inputs. But a few necessary elements should also be developed for increasing this mechanical input:

(i) Farmers must be educated in the care, maintenance and safe use of machines, implements and equipments.

(ii) A sales and service network should be established and a good repair parts inventory maintained.

(iii) Financial institutions should be established to provide capital for the purchase of agricultural equipment. The sales and service network as in (ii) may work also as financial institutions so that the farmers get the agricultural equipments from these.

(iv) Mechanics must be trained for minor and major repair and overhaul of machines.

(v) Marketing facilities are to be developed and appropriate transportation processing and storage facilities are to be provided.

(vi) Agricultural equipment and machinery industries are to be established. Since we have already progressed a little towards mechanization we should start establishing assembly-cum-manufacturing plants. There is a great scope of establishing such plants with technical and financial assistance from Japan. South Vietnam and Taiwan have started such plants with the help of Japan. The Machine Tools Factory at Joydevpur, Dacca have started manufacturing Diesel engines and power pumps. In the near future, the plant will manufacture 'Rotos' deep-tube-wells pumps with the assistance of an Italian Company. Possibilities of manufacturing power tillers and tractors in this factor should be explored. The Bangladesh Small Scale Industries Corporation (BSIC) have established many small scale industries but none of them are for agricultural tools and implements. There are 382 registered and unregistered small scale manufacturing units in the private sector for agricultural hand tools and implements. None of these are suitable for manufacturing of modern agricultural machines and implements. The government should take up these small scale manufacturing units and modernize them in a phased manner so that they can manufacture agricultural machinery and implements. There are 7 hand sprayer manufacturing units at present in the country but there is no power sprayer manufacturer. Steps should be taken so that power sprayers are manufactured in our country. In 1972-73, 12,000 tons of pesticides shall be applied and this figure shall be increased to 30,000 tons by 1975-76. Therefore, there is a huge requirement of power sprayers in the country. Instead of continuing to import them we should go for manufacturing them locally.

(iv) Agricultural elite and policy makers.

The elite and policy makers for agriculture, include not only the members of political parties, but also the top status of the government and semi-government organizations, ministries, agencies, corporations etc. These persons affect farmers and agricultural growth through the policies and programmes which they formulate for agriculture. The non-agricultural background and training of the existing agricultural elite and policy makers of Bangladesh is a serious factor affecting the rates of growth. Very few of these persons involved in agricultural policy making are specially trained in agriculture, even though most of them do have some form of advanced university education. Moreover, very few of them come from rural or agricultural backgrounds. But these persons are primarily responsible for formulating, implementation and evaluation of short or long term plans, development schemes and national policies. Both advisory and active part are played by them. The non-agricultural background and training of such people hampers understanding, sympathy, and communication betweem them and the rural people.

Evaluating the hydraulics of water advance front in an irrigation border to develop criteria for the design of efficient surface irrigation systems. Problem-oriented research is in progress throughout the country to develop the technology for efficient water management.

The policies and programmes formulated by them may often based on misconception or inadequate information due to lack of familiarity with basic facts of agriculture. The greatest need of Bangladesh is for those professionals who have a knowledge of national agriculture and its problems and has a sincere understanding and appreciation of rural people. It is likely that such characteristics may be possible to be found in the graduates of agricultural field including agricultural engineering graduates who should be given their due share of playing their role for agricultural growth of Bangladesh.

(v) Conclusion

In order for agricultural and economic development and growth of Bangladesh there is a necessity of consideration of setting priorities and balance: the balance between human and non-human capital within agriculture, and the balance between rural and urban development in economic growth. If we accept that certain measures are required to be taken for agricultural growth, then failure to utilize these measures to the fullest extent will result in a slower rate of agricultural growth. But the penalty of a slower rate of agricultural will not fall solely on the rural or agricultural sector: it will also affect the overall national rates of economic growth. Since agriculture is the basis of Bangladesh economy emphasis in agricultural sector of Bangladesh is the key determinants of the rapidity with which overall economic growth will take place. Therefore, considerable attention should be given to all aspects of agricultural growth for education, training, research and development, manufacture of agricultural inputs, transportation and communication, processing, preservation, storage, and marketing in parallel with other sectors of development commensurating with the available resources of the country. ■ ■

Corn soybean interplanting at 50 days

(Continued from p.155)

tember 4, 18, 1970.

(113) Finfrock, op. cit., December 18, 1970; Welsch, op. cit.

(114) Marion R.Larsen, Agricultural Economy of North ietnam, U.S. Department of Agriculture, ERS Foreign 123, April 1965, p. 10 (based on official statistics released in 1961).

(115) In 1961, Gourou indicated that 50% of the Delta area produced two crops (Pierre Gourou, The Tropical World: Its Social and Economic Conditions and its Future Status (trans. by E.D.Laborde), Longmans Green & Co., London, 3rd edition, 1961, p. 101).

(116) Some of the problems involved in shifting the peasants to double cropping of rice are noted in Gerard Chaliand, The Peasants of North Vietnam, Penguin Books, 1969, pp. 83-84.

(117) Pierre Gourou, The Peasants of the Tonkin Delta: A Study of Human Geography, Human Relations Area Files, New Haven, 1955, pp. 405, 412.

(118) Chaliand, op. cit., pp. 166, 174.

(119) Computed from data in Report on the Agriculture Census of Vietnam, 1960-1961, Department of Rural Affairs, Agricultural Economics and Statistics Service, Saigon, pp. 42, 48-61. (This report was kindly brought to my attention by Nancy Hancy Hancock of ERS.)

(120) Ibid.

(121) Yamada and Lusanandana, op. cit., p. 26.

(122) Agriculture Census, op. cit., p. 48.

(123) Ray S.Fox, "Rice Cost of Production in Vietnam, 1968/69," US/AID, Office of Associate Director for Food and Agriculture, March 1971, Table 1.

(124) Robert L.Sanson, The Economics of Insurgency in the Mekong Delta of Vietnam, MIT Press, 1970, pp. 77, 78, 88.

(125) Ibid., pp. 87-88.

(126 Department of State Airgram A-1357 from Saigon, March 12, 1969.

Review of Recent Country Data*

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The basic general features of multiple cropping have been outlined in the previous chapters. Since the exact nature of multiple cropping varies considerably, we now turn to brief reviews of the situation in 25 less developed nations and Japan.[1] Emphasis is placed on recent data on the extent of multiple cropping and the types of cropping systems.

The extent of coverage from country to country, it will quickly become evident, varies considerably. For some of the 25 nations very little information was found and only a paragraph or so is presented. For others, such as India, considerably more data is reported. Fortunately, the amount of information available seems to be roughly related to the importance in total area or index of multiple cropping in the nation.

Nearly all of the countries reported are in Asia: only Egypt, Nigeria, and Rhodesia are included from Africa; and Brazil, Guatemala, and Mexico from Latin America. (Note: These countries are omitted by the editor in this extract.) Much of what some might call multiple cropping in these continents is excluded because it is part of shifting agriculture.[2] Moreover, these regions have less irrigated land and are less densely populated than Asia. Still, more multiple cropping may exist in Africa and Latin American than is suggested here.

Hopefully this information will help fill out the more general points discussed in earlier chapters and further suggest areas of possible future research or study.

BURMA

Although Burma has a long history of irrigation,[3] little is known about multiple cropping. In recent years, several million acres have been multiple cropped (**Table 1**). The expansion of double cropping has borne a close relation to the expansion of irrigation. Future growth is reported to be dependent on the extension of tractor plowing; the work is stated to be beyond the capacity of bullocks.[4] Rice forms the basis for the rotation, but it is not clear what is planted as the second crop.

A study of a village of 113 farmers in lower Burma in 1959-1960 indicated that 300 acres out of 1700 were double cropped, for an index of 117.6. Groundnuts (peanuts) were planted as the second crop by 94% of the farmers. This practice originated in the village in 1956. It has reportedly proved quite successful, due primarily to three factors: (1) there is an assured market and adequate transport facilites; (2) little capital outlay is needed because of the availability of land, labor, and a simple technology; and (3) the crop makes an important and inexpensive contribution to the diet and is a significant source of cash income.[5]

Table 1. Multiple Cropped Area and Indexes, Burma

Period	Multiple Cropped	
	Area	Index
	(1,000 acres)	
1936/37 to 1940/41 avg.	1,218	107.0
1961/62	1,315	107.4
1962/63	1,658	108.7
1963/64	1,895	109.6
1964/65	2,036	110.4
1965/66	2,162	111.1

Source: - H. P. Richter, "The Union of Burma", in Agricultural Development in Asia (ed. by R. T. Shand), University of California Press, 1969, pp. 154, 156.

CAMBODIA

Multiple cropping has been practiced for centuries in Cambodia. Under the Khmer emperors a complex system of hydraulic works were built in the Mekong River basin nearly 1000 years ago which made triple and quadruple cropping possible.[6]

Yet today Cambodia is not known to practice multiple cropping to any great extent. As elsewhere, some vegetables may be grown on paddy fields after harvest for family use. And multiple cropping of vegetables is found along some river banks.[7] No quantitative data, however, are available on the extent of such practices.

Recently the Israelis have been assisting a test farm in Prey Phdau, in one of the poorest farming areas of the country, in anticipation of completion of the nation's first reclamation project. This area had meager rice crops in the wet season and was not able to grow anything in the dry peason. With irrigation it is

* This chapter is extracted from *"Survey of Multiple Cropping in Less Developed Nations"*, Dana G. Dalrymple, U.S. Dept., of Agr. cooperating with U.S. Agency for International Development. Washington, 1971, pp.60~97

possible to get two rice crops a year, and experiments have shown that with maximum irrigation three crops a year can be grown. The Israelis have also shown the Cambodians how to grow other crops to permit diversification.[8]

CEYLON

Double cropping in Ceylon is largely tied to rice. It is estimated that 563,400 acres of rice, 43% of the total rice area, was double cropped in 1966.[9] The proportion was higher in the wet zone, which has two monsoons; it was lower (35%) in the dry zone, which generally needs irrigation water in both seasons.[10]

Several irrigation projects in the dry zone expected to being about an increase in the double propped area. The Mahaweli Ganga project will make possible a second crop on 300,000 acres already in rice production, and it will reclaim 600,000 acres of new land on which double cropping will be possible. The Walawe project in southern Ceylon will bring 65,000 acres of net land into production which will be able to produce at least two crops a year.[11]

Just how much of the second crop area is planted to crops other than rice is uncertain.[12] In the hill country around Rahangala, however, thousands of acres are now sown to potatoes after rice. The fact that the paddy land is flooded reportedly reduces the incidence of bacterial wilt on potatoes.[13]

CHINA (Mainland)

More land is probably mutliple cropped in Mainland China than in the rest of the less developed world combined. In view of the long history of multiple cropping in China, and the immense size and population of the country, extensive multiple cropping is to be expected.

Estimated Area and Indexes

The estimated area involved and cropping indexes for the 1952-1959, and 1968 period are presented in **Table 2.**[14] The data for the 1950's seem to be fairly well established and accepted. More recent national statistics have not been released and it was only possible to piece together a 1968 estimate; as footnote 2 to Table 2 indicates, there is a difference of opinion on what the figure should be.

The index, in any case, is considerably higher in southern China than in northern China. Yoeh, who compiled the national index of 147.4 for 1968 reported in Table 15, indicated that the index in the south was 189.3, while it averaged only 119.0 in the north. One researcher who placed the national figure at 145.9, calculated an index of 187.0 in the south and 118.5 in the north.

The cropping index is highest in the provinces of Chekiang, Kwangtung, and Kiangsi. Provincial estimates vary more widely than the regional figures, but it appears that each was over 200 in the season and may have ranged from 235 to 237. According to one source, Hunan (also in the south) may also have been over 200, although another places it at less. Other provinces with indexes ranging from 160 to 200 include Kwangsi, Szechwan, Kiangsu, Anhwei, Hupei, Fukien, Kweichow, and Honan.

Forms of Multiple Cropping

The main forms of multiple cropping in Mainland China, moving north to south, are: (a) winter wheat followed by coarse grains such as millet or corn; (b) winter wheat followed by industrial crops such as oilseeds, tobacco, or cotton; (c) rice followed by a winter crop of barley, pulses, or rapeseed; and (d) two crops of rice.

Among individual crops, winter wheat is apparently most important in terms of double cropped area occupied. The relative distribution of area was reportedly about as follows in 1957:[15]

Winter wheat	45%
Rice	15
Pulses	15
Barley	7
Rapeseed	5
Otxer	12

Compared to similar data reported in Chapter II for 1931-37, the areas planted changed as follows: wheat +12.0%; rice +77.1%; pulses +51.5%; barley −43.3%, and rapeseed −55.7%.

While these crops are the main ones used in double cropping rotations, other crops are involved in a vast array of combinations. Some of the more unusual or interesting sequences include: cotton-cotton (Anhwei Province), cotton-winter wheat (Hupeh), corn-rice (Kwangsi), corn-soybeans (Hunan), corn-corn (Hunan, Kwangsi, Kweichow), rice-tobacco (Kwangsi), and rice-jute (Kwangtung).[16]

Some triple cropping is practiced. In the most southern portions of the country-the Luichow

Table2. Multiple Cropped Area and Indexes, Mainland China

Year	Multiple Cropped	
	Area[1]	Index
	(1,000 acres)	
1952	82,359	130.9
1953	87,719	132.7
1954	95,289	135.3
1955	101,104	137.2
1956	116,973	142.3
1957	112,195	140.6
1958	119,773	145.0
1959	103,117	138.9
1968[2]	127,388	147.4

[1]Converted from mou on the basis of 1 mou = 1647 acres. Includes green manure crops.

[2]Some qualified observers feel that the 1968 figures reported here are too high. One suggests that the actual situation more nearly approached 1957. Another places the index at 145.9.

Sources:-

1952-58. Ten Great Years, State Statistical Bureau, Peking, 1960, pp. 128-129. (Summarized in FAS report noted below.)

1959. Official sources.

1968. Derived from data compiled by Tung Yueh and reported in Foreign Agricultural Service Report No. HK0022 from Hong Kong, March 24, 1970, p. 3.

Peninsula and the island of Hainan-attempts have been made to move from double to triple cropping of rice wherever fertilizer and manpower are adequate.[17] It was recently reported that a commune in Tzekam succeeded experimentally in growing three crops of rice in 1969/70 and subsequently introduced triple cropping on more than 2,300 acres.[18] Somewhat to the north-where the frost-free season is still over 300 days-double cropping of rice may be followed by a winter crop of wheat. In the area along the south bank of the Yangtze, triple cropping may involve winter wheat, summer rice, and an autumn coarse grain or potatoes.[19] As with double cropping, many other combinations are utilized in these and other regions. Vegetable crops, as elsewhere, may be planted in more intensive rotations. The total area more than double cropped, however, is likely still very small.

Communist Policy

Multiple cropping has been promoted since the Communist regime came to power in 1949. There are only limited possibilities for land reclamation in the most important agricultural provinces. During the 1950's emphasis was placed on the development of two-crop rice; somewhat less attention was given to expanding rotations involving winter crops such as wheat or barley.[20]

In either case, the programs met with mixed success. The expansion of double cropped rice proved practical in the portions of south and central China with sufficient water supplies; the program was less successful elsewhere, particularly east China, primarily because of the relatively short growing season and shortages of labor at critical times. The expansion of winter crops in north China was limited by the fact that the cultivation of winter crops delayed the sowing of spring grains until summer, which in turn meant that they could not mature before arrival of bad weather. In some areas, therefore, the combined yield from double cropping was less than for single crops.[21]

Shifts in individual cropping patterns were also involved. Some of the increase in the double rice cropped area represented a shift from intermediate rice. The wheat area actually may be declining in favor of corn, millets and sorghum. Further, emphasis on increasing the area of green manure crops south of the Yangtze may have cut into the winter crop area.[22]

Current emphasis seems to be on further expansion of double cropping of rice. In order to accomplish this, the regime has been expanding irrigation facilities, providing more fertilizer, encouraging interplanting, and pushing the development of early ripening varieties.[23]

INDIA

India has the second largest multiple cropped area in the world, but her multiple cropping index is relatively low considering population density. In recent years the multiple cropped area has averaged about 50 million acres, but the cropping index has only been around 115 (**Table 3**). The rate of increase in the index from 1949/50 to 1966/67 has been slight; it may actually have decreased during the drought years of the mid 1960's. National data for more recent years, when multiple cropping may have expanded, are not yet available.

Even in some of the northen states where multiple cropping has been practiced since antiquity, the index is not exceptionally high. In 1965/66, the top four states-accounting for 56% of the total multiple cropped area-were: Bihar, 129; Jammu and Kashmir, 127.7 (a sharp increase from 1956/57); Uttar Pradesh, 127.3; and Punjab, 126.8. Other leading states were: Orissa, 124.3 (a sharp increase from 1956/57); Kerala, 123.6; Madras, 119.1; Assam, 118.9; and West Bengal, 117.4.[24]

Within Punjab, data from a sample of progressive farms show a rather striking increase in the cropping index in the late 1960's: from a figure of 126.7 in 1966/67 to 144.3 in 1969/70. This region, however, is perhaps the most advanced agriculturally in the nation and has been in the forefront of the Green Revolution.[25]

Influence of Irrigation

Normally one expects the cropping index to be higher in irrigated than in non-irrigated areas. This, however, is not the case in India where the indexes for both have been about the same at 115.[26] A surprisingly large portion (82%) of the double cropped area is reportedly in rainfed rather than irrigated

Table 3. Multiple Cropped Area and Indexes, India

	Multiple Cropped	
	Area[1]	Index
	(1,000 acres)	
1949-50	38,108	112.0
1950-51	32,486	111.1
1951-52	34,181	111.6
1952-53	35,169	111.5
1953-54	38,730	112.4
1954-55	40,119	112.7
1955-56	44,861	114.1
1956-57	45,916	114.2
1957-58	41,340	113.0
1958-59	48,928	115.0
1959-60	49,136	115.0
1960-61	48,330	114.7
1961-62	51,266	115.3
1962-63	50,465	115.0
1963-64(P)	50,468	115.0
1964-65(P)	51,931	115.2
1965-66(P)	47,119	114.0
1966-67(P)	48,456	114.4

[1] Area cropped more than once.

Sources:—1949-50 to 1965-66. Statistical Abstract, India, 1968, Central Statistical Organization, Department of Statistics, New Delhi, 1969, p. 56 (and earlier issues).

1966-67. "Department of Agriculture Pilot Project for Multiple Cropping," in Report of the National Seminar on Multiple Cropping, New Delhi, May 1970, p.14.

areas. Clearly, as an Indian report recently stated, "the irrigated potential has not so far contributed significantly to the increase of intensity of cropping."[27]

One of the major reasons irrigation has not played a larger role has already been discussed (Chapter III): the inadequate nature of much of the present irrigation system. In many areas barely enough water is available to supplement natural rainfall during the wet season, let alone provide adequate water for a second season. In the Western portion of the Gangetic Plain, for instance, the kharif rains are highly variable; irrigation water supplies are not similarly flexible except where pumpsets are available.[28] Timing of delivery is also a problem with canal irrigation.

Other reasons for the relatively low incidence of multiple cropping include: (1) the reverse problem of excess water and inadequate drainage many areas, (2) low soil fertility, and (3) a shortage of labor during the period when harvesting and planting functions overlap. In the eastern half of the Gangetic Plain it has traditionally been difficult to grow a crop of wheat after rice because the rice is harvested so late that the wheat cannot be planted soon enough; hence yield and profitability are depressed.[29]

Improvements in irrigation associated with the recent expansion of tubewells in some areas may well provide a more positive stimulus to multiple cropping.

Expansion of Multiple Cropped Area

India has a well-defined program to expand multiple cropped area. The Ford Foundation also has a complementary Intensive Agricultural Districts Program.

One of the earliest concentrated efforts to increase multiple cropping was made in Tanjore. There, during the middle 1960's, out of some 1.2 million acres of rice, only 25% or 300,000 acres were double cropped. A project was initiated to convert the single cropped land to double cropping by use of a new early maturing variety (ADT-27); the area so planted increased from 200 acres in 1964 to 200,000 in 1966. As of 1970, perhaps half the area was sown more than once.-[30]

A more general multiple cropping effort was undertaken in 1967/68. During 1968/69, some 15 million acres of a number of crops were covered under the program. A target of 19.45 million acres was established for 1969/70, or an increase of 4.45 million acres. The aim is to raise two to three crops a year in fully irrigated areas and two crops in partially irrigated mono-cropped areas. The techniques involved, in addition to new varieties, include improved irrigation and management practices. Members of the Ford Foundation in September 1970 indicated that 51 pilot projects in multiple cropping would be launched.[31]

The amount of multiple cropping achievable in the future is uncertain. It will depend, of course, on the possibilities for introducing new crops and for expanding irrigation, fertilizer and other inputs. Well irrigation is expected to be particularly important.[32] Taking current plans into account, the National Council of Applied Economic Research in New Delhi has recently made some projections of multiple cropped area as part of a larger project. The projections are summarized in **Table 4.** Using 1964/65 as a base, it will be noted that the multiple crop area is expected to double by 1980/81 and the cropping index to increase from 115 to 131. An ambitious target.

Types of Sequences

Many multiple cropping sequences are needed in a country as large and varied as India. In normal practice, double cropping may be the maximum possible under natural rainfall conditions. Where irrigation is present, triple cropping may be practiced.

Commom double cropping rotations include: hybrid maize-wheat, hybrid jowar-wheat, hybrid bajra-wheat, rice-wheat,

An unlined distributory of a canal irrigation system. Seepage forms the main source of water loss in irrigation projects. The loss may be as high as 25 to 40 per cent in a long unlined field water course in a sandy or sandy loam soil.

Table 4. Projections of Possible Multiple Cropped Area and Indexes, India[1]

Season	Multiple Cropped	
	Area	Index
	(1,000 acres)	
1964/1965	49,900	115.2
1970/71	61,800	117.7
1975/76	81,500	123.7
1980/81	103,500	129.7
1985/86	111,200	131.0

[1]Projections for 1975-76 and thereafter estimated on basis of "increase in the irrigated land available for cultivation...and in the light of the measures to be taken by the Government to introduce short duration varieties of crops."

Source:—Calculated from data in "Demand and Supply Projections of Food Grains for India, 1970-71 to 1985-86," Center for Agricultural and Economic Development, Iowa State University, DSR-3 (preliminary), October 1970. (Based on work by the National Council of Applied Economic Research, New Delhi.)

and rice-rice. Rice double cropping, as in other nations, is the most demanding with respect to water; the introduction of the early-maturing varieties, however, has facilitated its adoption (as well as, in some regions, the use of rice-wheat rotation).[33]

Triple cropping rotations have perhaps been the most widely studied. This has in part been accomplished by replacement of the traditional summer green manure crop with a short-duration pulse crop (such as moong),-[34] grain (such as cheena)[35], or forage (such as jowar). It was reported that during 1968/69, maximum production from three grain crops was achieved from maize-wheat-cheena and rice-rice-rice rotations.[36] Rice triple cropping, however, is not widely practiced. In North Bihar, a rice-rice-wheat rotation has been tested along with an alternate involving rice-corn-wheat.[37] Reportedly profitable rotations tested elsewhere include: radish-wheat-jowar and potato-wheat-jowar,[38] corn-potato-potato, corn-potato-tobacoo, and maize-potato-pumpkin.[39]

A particularly comprehensive and complete economic evaluation of alternative triple cropping rotations was conducted for the Tari region in Uttar Pradesh, an area well supplied with water. The guiding principal in establishing the rotations was the maximization of overall profits per acre per year. Ten "highly profitable" rotations were proposed; they are summarized with relevant economic data in **Table 5**.The corn-potato-corn rotation appeared to be most profitable. Selection of the most appropriate rotation, however, would be influenced by the availability of labor and capital and soil type. While labor requirements are quite high in many of the rotations, they are generally uniformly distributed over the different seasons.[40]

Quadruple cropping is not common, but research carried out by the Indian Agricultural Research Institute showed that it is possible to carry out such rotations utilizing only the same amount of fertilizer recommended for a double cropping sequence of corn and wheat. The tested rotation involved:(1) a legume (such as moong) which is grown on residual fertility, (2) a cereal crop (such as corn) which gets the advantage of the preceding legume and which is also fertilized, (3) a second grain (such as wheat) which is also fertilized, and (4) an oil seed (such as toria) or potatoes.[41] A slight variation of this rotation is finding favor in the New Delhi area: moong-maize-potato-wheat.[42] Yet another rotation is jowar-jozar (ratoon)-radish-wheat.[43]

Numerous other current multiple cropping rotations have recently been reported in a special issue of Indian Farming: "Accent on Multiple Cropping" (October 1970).

INDONESIA

Indonesia is composed of a number of islands, the most important of which is Java. The type of agriculture practiced on Java (and its close neighbor Madura) is much more intense than that followed in the outer islands. Hence most of the multiple cropping is found on Java, although a limited amount of multiple cropping is carried out elsewhere.[44]

It is not known how long multiple cropping has been practiced on Java, but it appears to have increased with the growth

Table 5. Indexes of Labor Requirements and Net Returns Under Various Triple Cropping Systems, Uttar Pradesh, India, 1967

System	Input Requirements					
	Labor[1]		Capital		Net Returns[2]	
	Index	(Rank)	Index	(Rank)	Index	(Rank)
Maize-potato-maize	100	(1)[5]	100	(1)	100	(1)
Soybean-wheat-cheena[3]	43	(9)	52	(6)	86	(2)
Maize-sugarbeet-cheena	64	(4)[6]	60	(2)	84	(3)
Soybean-wheat+sugarcane-maize[3],[4]	53	(8)	51	(8)	80	(4)
Maize-lahi-wheat	54	(6)	54	(5)	79	(5)
Rice-pea-maize	81	(2)[5]	58	(3)	73	(6)
Rice-wheat-gram	54	(6)	54	(4)	68	(7)
Maize-lahi-sugarcane+maize-sugarcane ratoon-maize[4]	57	(5)	48	(9)	66	(8)
Maize-lahi-maize	70	(3)	51	(7)	56	(9)
Rice-gram-cheena	55	(7)	45	(10)	53	(10)

[1]Number of man units required per hectare per year.

[2]Average annual net returns.

[3]Adoption on wide scale depends on possibilities of increasing soybean market.

[4]Two-year rotations. Recent increase in sugar prices responsible for higher degree of profitability than would have been true in past.

[5]High but fairly uniformly distributed.

[6]High and concentrated.

Source:-New Intensive-Cropping Rotations in Tari, U. P. Agricultural University, Experiment Station, January 1968, pp. 17, 44-47.

of population after 1900. Rice, the basic crop, was double cropped on paddy or watered fields and joined by other crops in the dry areas.[45]

Just what the current multiple cropped area and indexes are, is uncertain. One set of data for the period from 1955 to 1964 show suspiciously wide variations from year to year (**Table 6**). Still, one might settle for a rough average of 4 million acres and an index of 120 or so.

How do other estimates compare? Jacoby reports indexes of 131 in 1926 and 142 in 1936 for Java, but these seem high on an island-wide basis.[46] The Asian Agricultural Survey indicates that in 1962 no more than 2.16 million acres or less than 25% of the 8.65 million acres of rice land were planted to a second crop of rice.[47] Corn and sorghum are commonly planted as a second crop where dry season irrigation is not adequate. Other off-season crops also include peanuts, soybeans, beans, fruits and vegetables, and cassava. [48] The area of these also planted during the dry season has not been reported separately.

Whatever the actual multiple cropping level, it has probably not changed much since 1962.[49] The lack of water seems to be

Table 6. Multiple Cropped Area and Indexes: Indonesia (Java and Madura)

Year	Multiple Cropped	
	Area	Index[1]
	(1,000 acres)	
1955	828	104.0
1956	2,100	110.3
1957	2,209	110.7
1958	4,314	121.4
1959	3,222	115.3
1960	4,040	119.6
1961	2,585	112.3
1962	4,359	121.6
1963[2]	1,584	107.6
1964[2]	5,248	126.2

[1] Total harvested area as 3 per cent of arable land.

[2] Preliminary.

Source:-Nugroho, Indonesia Facts and Figures, Terbitan Pertjobaan, Djakarta, 1967, pp. 237-238.

Figure1 Northern Limits of Cropping Systems in Japan

(Source: Robert B. Hall, "The Japanese Empire," Economic Geography, October 1934, p. 339.)

one of the big handicaps. In many parts of Java there just isn't enough water for year-round cultivation, although efforts are being made to put the land to better use.[50] The World Bank and the Asian Development Bank are making funds available for rehabilitation and construction of irrigation works.[51]

Still, the population is already so dense in some regions that, as Penny puts it, "all the irrigation in the World won't make the people prosperous." He reports visiting an irrigated village in the Jogjakarta area of middle Java, where nearly all the residents depend on agriculture, where the population density has reached the incredible level of 4,600 persons per square mile![52]

IRAN

An unknown amount of multiple cropping is practiced in the Caspian area and the south of Iran in Khuzistan. The leading rotation is composed of grain or summer crops followed by sesame; other rotations include wheat or barley followed by rice, and leafy vegetables followed by summer crops. The leading summer crops are melons, watermelons, tomatoes, and recently, cotton. [13]

As part of a broad development program, the Development and Resources Corporation in California has proposed four alternate cropping patterns for large-scale agricutural enterprises in Khuzistan. An intensive rotation, which has a cropping index of 160,includes grains, vegetables, sugar beets, and beans. It is fully mechanized.[16]

IRAQ

Despite the fact that the Tigris-Euphrates River area was one of the early homes of perennial irrigation and multiple cropping, very little information seem to be available. One review of agriculture in Iraq suggested that the double cropped area in 1958/59 might have been around 60,000 acres, a good part of which was probably vegetables.[55] Another work indicates that pumps are

Table 7. Multiple Cropped Area and Indexes, Japan (Includes Green Manure Crops)

Year	Multiple Cropped Area	Multiple Cropped Index
	(1,000 acres)	
1950	6,336	152
1952	5,747	144
1956	6,246	144
1957	6,020	143
1958	5,910	142
1959	5,654	140
1960	5,755	140
1961	5,565	139
1962	5,525	139
1963	5,112	136
1964	4,678	133
1965	4,300	131
1966	4,030	129
1967	3,672	126

Sources:—Annual reports of the Ministry of Agriculture and Forestry: Statistical Yearbook; and Abstract of Statistics on Agriculture, Forestry and Fisheries.

increasingly being used to provide a year-round supply of water; they enable barley, millet and wheat to be grown in the winter and rice in the summer.[56]

JAPAN

Japan's climate largely determines the multiple cropping patterns followed. This is depicted in **Figure** 1. It will be noted that double copping was limited essentially to the lower half of the nation in the early 1930's; the limits may have moved north somewhat since then. Most of the double cropped area is suited only to summer rice and a "dry" winter crop such as wheat or barley. Only a very small portion is suitable for two crops of rice. The multiple cropping index increases as one goes south.[57]

Japan is one of the few countries in the world to show a declining index of multiple cropping (**Table** 7). The decline is principally due to a drop in the area planted to dry winter crops. The area of rice double cropping has held about steady. Opinions vary as to the reason for the decline. Barse suggests that the area of dry winter crops has dropped off because of two major factors: (1) a decrease of farm labor availability due to shifts to other employment or to retirement, and (2) low returns, especially from barley.[58] Sawada thinks that the decrease in double cropping was due to the growing import of grains.[59]

Only about 26,000 acres or less than one percent of the total multiple cropped area was planted to two crops of rice during the 1960 to 1969 period.
Nearly all of this is found in Kagoshima, Kochi, and Miyazaki perfectures.[60] As noted earlier, the practice originated in Kochi several hundred years ago and reached a peak in 1932; it declined thereafter due to pest and disease damage and a shortage of labor. After World War II the area began to expand modestly: the introduction of high-yielding varieties brough about its spread to Kagoshima and Miyazaki.[61]

KOREA(South)[62]

Double cropping is extensively utilized in South Korea. During the 1960's the index for the nation averaged about 152, with no clear trend (**Table** 8). Of the tatal double cropped area in 1969, about 52% was paddy land and 48% upland fields (the paddy proportion incresed during the 1960's, while the upland proportion declined). Of the total paddy land in 1969, about 50% was double cropped; the similar portion for upland was about 58% (again the paddy proportion increased during the 1960's and the upland portion declined).

Table 8. Multiple Cropped Area and Indexes, South Korea

Year	Multiple Cropped Area	Multiple Cropped Index
	(1,000 acres)	
1960	2,328	146.1
1961	2,556	150.5
1962	2,590	150.4
1963	2,673	151.6
1964	2,911	153.8
1965	3,243	157.7
1966	2,890	150.6
1967	2,990	151.9
1968	3,001	151.9
1969	3,074	153.4

Source:—Computed from data in Yearbook of Agricultural and Forestry Statistics, Ministry of Agriculture and Forestry, Seoul, 1970, pp. 66, 76.

As elsewhere, there are considerable geographic variations. Overall, most of the double cropping is concentrated in the central southern portions of the country because of climatic and soil conditions. Paddy and upland fields, however, show quite different patterns. Most of the double cropping on paddy land is concentrated in the south, while upland double cropping shows a much more uniform distribution.[63]

The major off-season crop is barley. Accorging to one survey in the mid-1960's barley made up 89% of the total double cropped area; wheat accounted for 5%. Rye was grown on the poorer lands. In the North, the second crop was largely devoted to feed crops.[64]

Despite weather constraints, it is felt that more cropping could be carried out. The reason, according to Shim, is economic; double cropping just doesn't pay the farmer enough. Both yields and prices are low. The potential for improving the situation as reported by Gasser, et al., varies by crops [65]

—Barley. There are very good prospects for improving the yield of barley through better cultural practices including liming, varietal improvement, and more favorable price-cost relationships. Although demand for barley as a food will decrease as the standard of living rises, there are real possibilities for use as a livestock feed. Despite this potential, relatively little research is being done.—

—Wheat. Considerable research has been done on wheat as a second crop. The main problem at present is that the growing season is about two weeks longer than for barley. Emphasis is being placed on breeding earlier-maturing varieties.

—Rice. The growing season is too short to readily grow a second crop. It is technically possible to grow two crops (by setting out seedlings under vinyl hot beds) but, because of the limited growing season, yields of both are reduced.

Finding or developing a crop which can both achieve high yields and be in strong demand will be a considerable challenge. In addition it may be necessary to give attention to mechanization to shorten the "turn around" time in the spring and fall. Irrigation and drainage continually need improvement.

LAOS

Until recently, multiple cropping was practiced to only a very limited extent in Laos. A change occurred during 1966/67 with the introduction of the new short-season rice varieties from the Internation Rice Research Institute. Nearly all the second crop farming since then has been rice grown under irrigation during the dry season. Areas so planted are estimated as follows:[66]

Year	*Area* (acres)
1967/68	2.390
1968/69	4.440
1969/70	3,100
1970/71	3,580

Emphasis is now shifting from rice to other crops such as corn, sorghum, soybeans, and peaunts.

A number of projects are under way which will extend the irrigated area during both the wet and dry seasons. In March 1970, the Asian Development Bank approved a loan to the Laotian Government which will enable it to transform about 2,000 acres of unused land in the northern part of the Vianentiane Plain into year-round irrigated farming. Both rice and vegetables are to be produced.[67]

The rather relaxed attitude of some Laotian farmers towards such intensive activities has already been noted in Chapter III. In addition, it is reported that some farmers are not interested in dry season rice because they feel it will leave them or their buffalo too tired to work efficiently the following wet season.[68] There are, however, other factors which limit adoption: (1) many of the young men have been inducted into the military service, leaving only the old men, women, and children to do the farming; (2) internal transportation is poorly developed. Since many of the Laotian centers of population are just across the Mekong River from Thailand, which has a relatively good road system, more food is imported than would otherwise be the case.[69]

LEBANON

Although Lebanon is one of the most densely populated nations in the world in terms of agricultural land per capita, multiple cropping is very limited. The U.S. agricultural attache in Lebanon estimates that out of approximately 178,000 irrigated cultivated acres, only about 2,600 (or roughly 1.5%) are multiple cropped. Of the multiple cropped area, practically all is double cropped; only about 124 acres are triple cropped. The three areas where multiple cropping is found are the North Coast (mainly the Akkar Plain), the Central and South Coast, and the Central Beka'a Valley. In nearly every case the rotations are built around vegetables; on the North Coast the rotation involves early potatoes (harvested in June) and late peanuts (harvested in late October and November).[70]

MALAYSIA

Two quite different cropping systems are found in the two major portions of Malaysia. West Malaysia (on the Malay Peninsula) follows a traditional paddy field system, whereas a slash and burn system is found in East Malaysia (Sabah and Sarawak). Thus agriculture is much more modern and yields correspondingly higher in the West than in the East. In both cases, rice is the staple food.[71]

West Malaysia

The statistics on multiple cropping in West Malaysia are limited to the rice area double cropped. Still, they probably reflect nearly all the multiple cropped area.

The area of rice land reportedly double cropped has expanded very sharply since the middle 1950's: from 6,400 acres in 1956/57 to 238,000 in 1969/70. Two sets of estimates by years

Table 9. Estimated Rice Area Double Cropped, West Malaysia

Season	Estimate	
	AAS[1]	FAS[2]
	—thousands of acres—	
1956/57	6.4	
1957/58	7.2	
1958/59	10.4	
1959/60	20.0	
1960/61	35.1	
1961/62	46.0	47
1962/63	48.7	49
1963/64	57.8	58
1964/65	88.7	90
1965/66	103.3	104
1966/67		157
1967/68		225
1968/69		238

Notes:
[1]Rice double-cropping area.
[2]Planted to off-season rice crops. The harvested area was usually about one thousand less.

Sources:—
AAS. Noboru Yamada and Bhakdi Lusanandana,"Rice Production in the ADB Region," in Asian Agricultural Survey, Vol. II, March 1968, p.30.
FAS. Foreign Agricultural Service Report No. MY0009 from Kuala Lumpur, May 8,1970 (Enclosure 1, pp. 1-2).

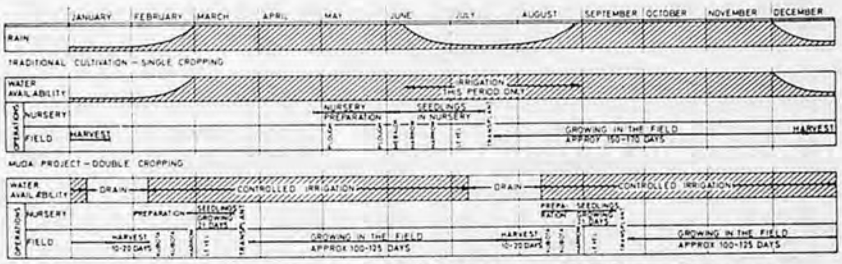

Figure2.Traditional Cultivation Compared with Multiple Cropping, Muda Project, West Malaysia

(Source:—"Muda River Project," *World Crops*, March/April 1969, p. 13.)

are reported in **Table** 9. The figures are very close for the five year overlap period.

Off-season rice plantings were begun by Chinese farmers in Province Wellesley on the northwest coast during the Japanese occupation in the mid-1940's when food was in short supply.[72] Some 30,000 acres were double cropped in Province Wellesley in 1969. A further 22,000 acres were found at Tanjong Karang at Seleangor and another 10,000 acres in the Kedal plain (where experimental trials were started "some years back").[73]

The recent and projected expansion in area is tied in with the development of several irrigation schemes. The Sungei Muda project will enable farmers in the principal rice bowl in the states of Kedah and Perlis (on the northwest coast) to grow a second crop on 130,000 acres in 1970, 234,000 in 1971, and 261,000 in 1972. To the south, the Kemubu scheme will make it possible to double crop another 47,000 acres.[74]

Early maturing rice varieties are expected to play a major role in making double cropping possible. The extent to which crops other than rice will be planted is uncertain. A comparison of the single and double cropping patterns in the Muda Project is provided in **Figure 2**

The Asian Development Bank has recently provided a loan of $4.2 million to provide irrigation to make double cropping possible on 12,600 acres of paddy fields in the state of Trengganu. Total cost of the project is expected to be $7.1 million.[75]

East Malaysia

Double cropping has been very limited in Sabah and Sarawak for several reasons: rubber has been considered a more profitable crop than rice, the population is relatively small, and there has been an absence of any real hunger. Recent government policy has been to increase the level of local rice production and this, together with a scarcity of good fertile land, has led to interest in growing a second crop of rice.[76] Experimental work done at the Tuaran Agricultural Research Station in Sabah showed that double cropping was possible. In 1968 an estimated 4,000 acres produced two crops.[77]

NEPAL

The southern edge of Nepal, known as the Terai, is part of the Ganges Plain and is intensively cropped. Double cropping is practiced, and in the areas where good irrigation facilities are available, triple cropping is carried out. Rice is the major monsoon season crop, while wheat and some pulses are planted during the winter period. Winter crops are grown on only about 1/4 of the rice and jute land in the Terai and not all of this may represent multiple cropping. In the Inner Terai, mustard is double cropped with rice or corn. A rice-wheat rotation is also used in the midlands (Mahabharat sector). On the high terraces a rotation of maize followed by millet is the common practice. In the higher altitudes, short-term barley may be followed by buckwheat.[78]

PAKISTAN

Physically, East and West Pakistan are quite different. East Pakistan is a low-lying, relatively wet region where rice is by far the main crop. West Pakistan is a relatively arid area which has wheat as a main crop. The population density is much greater in the East than in the West.

The Indexes

For these reasons, one might expect a much higher multiple cropping index in the East than in the West. Such is the case. As may be seen in **Table 10**, which is based on official data, the index in the East in recent years has averaged about 138, while that in the West has been about 112.

The precise index figures, however, are suspect on several counts. Since the population density in East Pakistan is one of the highest in the world, it is surprising that the index is not larger.[79] Part of the answer may be that much of the cropland is flooded part of the year (though this may enhance cropping the rest of the year), and the country is extremely poor and has not yet had the resources—technical and financial—to develop off-season production to its maximum level. Still, the trend seemes to be very gradually upward.

No special trend was apparent in the West through 1963/64; since 1964/65, however, the area seems to have decreased. The recent decline, even assuming that 1964/65 was an unusual year, is most difficult to understand because there has been a sharp increase in the use of tubewells and early maturing varieties of wheat and rice during this period. Farm management studies, in fact, reveal that in Tehsils of Peshawar and Nowshera where adequate water was available,

Table 10. Multiple Cropped Areas and Indexes, East and West Pakistan

Season	East Pakistan		West Pakistan	
	Multiple Cropped[1]		Multiple Cropped[1]	
	Area	Index	Area	Index
	(1,000 acres)		(1,000 acres)	
1949—50	5,564	127.6		
1950—51	5,708	127.8	3,131	111.1
1951—52	6,080	129.4	2,333	108.4
1952—53	6,574	131.4	2,066	107.4
1953—54	6,909	133.1	2,825	109.4
1954—55	6,572	131.4	3,503	112.0
1955—56	5,509	126.9	3,875	112.7
1956—57	5,468	126.7	3,774	112.1
1957—58	5,620	127.7	2,405	111.0
1958—59	5,366	127.0	4,520	114.3
1959—60	5,902	128.7	3,105	109.6
1960—61	6,732	132.3	2,421	107.5
1961—62	6,453	130.8	3,447	110.4
1962—63	6,796	132.5	3,187	109.4
1963—64	7,095	133.7	4,191	112.9
1964—65	7,434	135.2	5,140	114.7
1965—66	7,940	136.8	4,473	112.9
1966—67	7,926	137.6	4,116	111.7
1967—68	9,694	144.6	3,046	108.5
1968—69	8,479	139.2		

[1] Area sown more than once during one season (see discussion in text).

Sources:-

E. P. East Pakistan Agriculture, 1968-69, USAID, Dacca (enclosure to FAS Report PK 0064, September 8, 1970).

W. P. 1949-50 to 1965-66. Pakistan Statistical Yearbook, 1967, Central Statistical Office, Karachi, 1968, p. 76.

1966-67 to 1967-68. Official data provided by Jerry B. Eckert, The Ford Foundation, Lahore, November 6, 1970.

the intensity of cropping increased from 1964-65 to 1968-69; in irrigated regions in Rawalpindi and Multan additional area was put in vegetables.[80]

Subsequent investigations have revealed that the official figures for West and presumably East Pakistan are, in fact, in error. It seems that the data reflect the amount of multiple cropping reported in each of two inspections during the year; thus the amount of double cropping reported refers only to one season and not the year. Hence the amount of double cropping is sharply underreported. The problem is particularly severe in West Pakistan where wheat has been replacing two shorter season crops in recent years, thus bringing about a decline in the reported cropping intensity, if not in land use intensity. The government subsequently began to recalculate the data for the past four years; preliminary tabulations show sharp differences.[81]

East Pakistan

In many ways, as suggested, East Pakistan is a most appropriate area for multiple cropping. The climate generally permits a wide range of crops to be grown year round. The main problem is water control; much of the area is flooded in the wet season and irrigation is needed in the dry season. As progress is made in these and other areas such as research and the provision of capital, the index of multiple cropping may be expected to increase.

There are basically three growing seasons available during the year in East Pakistan. Paddy rice occupies about 95% of the total cropped area and in many places is reportedly harvested in each of the three seasons.[82] The amount planted is least during the winter or boro season because of limited rainfall. Still, other crops with lower water requirements could be planted during this period, and more rice could be planed if irrigation were available.

The installation of tubewells began in the Comilla area in East Pakistan in 1962 with the intention of promoting winter planting of a third crop. By 1964-65, the project sponsors were experiencing difficulty because the farmers "showed a lack of knowledge about... the profitability of winter cropping by means of tubewell." Cost and return studies were carried out on the 1965-66 crop and showed that the growers taking to winter irrigation and cropping were earning a "handsome profit".[83] By 1969 a total of 11,400 pumps had been installed in the Comilla District, and during 1970 the figure was expected to rise to 18,000. More than 500,000 new irrigated acres were under cultivation, over a third of which was devoted to IR-8 rice.[84]

West Pakistan

Because of its dryer climate, irrigation has been of even more importance in the growth of multiple cropping in West Pakistan. This close relation was suggested in a study in 1962.[85] The type of irrigation, moreover, is of further significance; a survey in the Punjab the winter of 1967 indicated that the cropping intensity for growers of cotton and rice using canal irrigation was only 90, while that for tubewell farmers was 135.[86]

Both studies, as well as the 1960 census, also suggested an inverse relationship between farm size and cropping intensity. This disparity, however, was reported to decrease in the Punjab with the installation of tubewells; they appeared to raise the cropping intensity of the larger farms proportionally more than the smaller farms.[87]

PHILIPPINES

Multiple cropping data for the Philippines are not entirely clear or consistent. On the one hand, statistics reported in the Census of Agriculture suggest the following multiple cropped areas and indexes (some intercropping may be included)[88]:

Year	Multiple Cropped Area (1,000 acres)	Index
1938	2,607	127
1948	2,357	126
1960	4,982	136

On the other hand, partial data from other sources suggest considerably lower figures. Jacoby notes that in 1938 a total of nearly 580,000 acres of rice and corn were planted more than once; writing in the late 1940's he placed the double cropped area at 6 to 8% of the total crop area.[89] Elsewhere it has been estimated that about 1.235 million acres of rice, or approximately 15% of the total rice area, were double cropped in 1965.[90]

Survey data from the 1950's and 1960's while not exactly comparable, tend to confirm the general cropping index level reported for 1960. A survey of 5,179 farms in 1954/55 revealed that 34% of the cropland was double and/or intercropped (ranging from 21% to 67% between regions); of the 3,801 farmers in this group who were classified as lowland rice farms, 33% planted a second crop (19% rice, 14% other).[91] Another survey carried out among 292 lowland farms in 1962/63 showed an index of about 148 (approximately 20% of the farmers raised a second crop of rice while the rest planted other second crops).[92] A third survey of 50 farms conducted in 1968-69 revealed in 1968-69 revealed an index ranging from 100 to 213, depending on the type and size of farm.[93]

In some regions, the cropping indexes are higher for upland than lowland rice farms. This has occurred in Batangas, where it is possible to carry out multiple cropping within the existiting rainfall pattern.[94] The irrigation systems in the lowland areas are designed primarily for the production of rice and they lack the controls necessary for the production of most alternative crops.[95]

Most vegetable farms grow three crops a year. On the low land in Laguna, either two crops of tomato or three of cucumber can be raised. In the Baguio area, four crops may occasionally be produced.[96]

Some of the most advanced research in the world on multiple cropping has been undertaken by Dr. Richard Bradfield, an agronomist, at the International Rice Research Institute. Utilizing exceptional growing conditions, Dr. Bradfield has developed some very sophisticated rotations, involving the cultivation of five crops a year. Four of the leading combinations, as reported in 1968, are presented in **Figure 3**

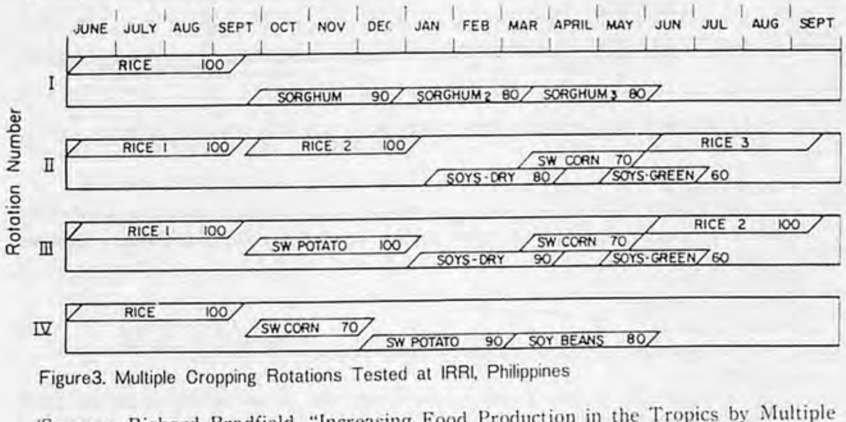

Figure3. Multiple Cropping Rotations Tested at IRRI, Philippines

(Source:—Richard Bradfield, "Increasing Food Production in the Tropics by Multiple Cropping," in *Research for the World Food Crisis* (ed. by Daniel G. Aldrich Jr.), American Association for the Advancement of Science, Publication No. 92, 1970, p. 242.)

According to Bradfield, these sequences give a good distribution of planting and harvesting dates thoughout the year. They also make marketing, especially of vegetables which are sold in the fresh state, much simpler. The frequent harvests, Bradfield suggests, give the farmer something so sell regularly and simplify his credit problems.[97]

The cultural conditions for this work at IRRI and the complex nature of the rotations may put them out of the reach of most farmers. But they do provide an idea of the upper limit of what can be accomplished. Hopefully, more reports on this work will be forthcoming. An agricultural economist has recently joind the project and will study the costs and returns from such rotations.

TAIWAN

Multiple cropping has probably reached its highest stage of commercial development in the free world in Taiwan. This development, as we have noted, largely seems to have been a product of the 20th Century. It was not due to any great gift of nature; indeed, the opposite was true. The lack of land and a large population made multiple cropping necessary. The process was initiated when Taiwan was under Japanese rule and was facilitated by the technical and capital improvements made during this period.

Multiple cropping indexes in Taiwan over the past 20 years (**Table 11**) have been higher than for any nation in the world, though possibly not for certain provinces in Mainland China. The high point, an index of 190, was reached in 1966, and in the subsequent three years the index declined slightly. The recent drop

Table 11. Multiple Cropping Area and Indexes, Taiwan

Year	Multiple Cropped	
	Area	Index
	(1,000 acres)	
1950	1,500	169.7
1951	1,505	169.7
1952	1,557	171.9
1953	1,564	172.5
1954	1,594	173.8
1955	1,537	171.3
1956	1,633	175.5
1957	1,705	179.0
1958	1,745	179.9
1959	1,769	181.5
1960	1,794	183.6
1961	1,848	185.8
1962	1,838	185.3
1963	1,826	184.7
1964	1,917	188.0
1965	1,964	189.4
1966	1,992	190.0
1967	1,947	187.4
1968	1,962	188.2
1969	1,905	184.3

Sources: -1950-1968. Taiwan Agricultural Yearbook, 1969 Edition, Department of Agriculture and Forestry, June 1969, p. 21.
1969. Letter from C. L. Luh, Plant Industry Division, Joint Commission on Rural Reconstruction, Taipei, August 8, 1970.

in the index according to Cheng, may be traced to (1) a tightening of the labor market due to rapid industrial development, (2) increased cost of inputs, and (3) increased competition from large scale imports of lower priced soybean, corn and wheat beginning in 1967 (these imports were made to encourage the development of the local livestock industry).[98]

Within the island, the cropping indexes, as elsewhere, vary considerably by prefecture. In 1960 and 1961 the range was from a low of 132 in Penghu to highs of 232 and 233 in Taichung and Changhua.[99] The differences are quite pronounced between the central and southern portions, as illustrated below:[100]

	Redion		
Year	Central	South	Country
1950	212	162	170
1955	213	167	171
1960	234	172	184

A number of cropping systems are followed. Some are summarized in **Figures** 4.[101] It can be seen that two crops of rice from the basis for the rotations, with dryland crops rotating in between. Some pure vegetable rotations involve six to seven crops a year. Due to timing problems in the more intense sequences, it is sometimes necessary to plant some crops between the rice rows before the rice is harvested.[102]

A significant portion of some crops are produced as second, third or fourth crops on paddy fields. In 1968, the following proportion of total production of each crop was raised in this way:[103]

Wheat and Flax	100%
Tobacco	99
Soybean	81
Vegetables	51
Corn	42
Sweet Potatoes	14
Sugar Cane	9

Crops not raised in this way may be produced part of rotations on upland or dryland fields.

THAILAND

Although multiple cropping has been practiced in ceratin areas in Thailand for many years, as of 1970 the area was still quite limited. Overall, it probably reperesents considerably less than 1% of the planted area.[104] In certain zones such as the concentrated corn area in the central highland, however, it may account for up to two-thirds of the cropland.[105] The area in off-season paddy in the Central Plain was reportedly 6,200 acres in 1963 and 123,600 in 1968.[106] Vegetables are grown year-round in the Bangkok area; in Chiengmai region they are raised between rice crops.[107]

With the construction of the Chainat Dam and the Chao Phya Delta Project, the area multiple croppea increased from 67,700 acres in 1966 to 188,600 in 1967; both rice and upland crops were involved. In 1970 it was reported that the potential had been created to supply water to dry seson crops over 153,000 acres; the goal for 1974 is 544,000 acres (of which 198,000 will be in rice and 346,000 in other crops.[108]

As we have noted earlier, there has been considerable debate as to whether rice or other crops should be planted on the newly irrigated land.[109] The debate may be nearing an end, however; a recently completed land use classification has shown that in the northern part of the Chao Phya Project no more than 12% of the land is suitable for irrigated production of crops other than rice in the dry season. Other uses

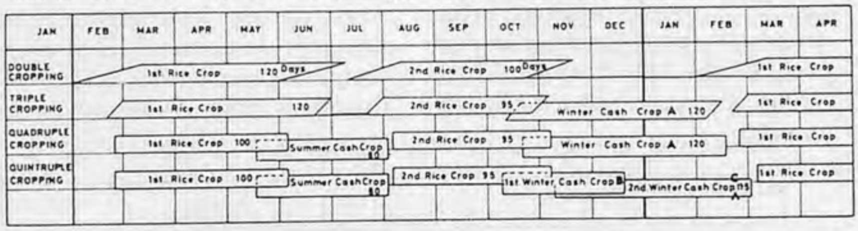

Figure4. Changes in Croppiog Patterns Involved With Higher Intensities of Multiple Cropping, Taiwan

Key to crops:
Winter Crop A
Wheat, barley, buckwheat, maize, soybean, sweet potato, rapeseed, field pea, tobacco, flax, green manure crop (green bean), broccoli, cauliflower, Chinese cabbage, or tomato.
Winter Crop B
Native cabbage.
Winter Crop C.
Wheat, maize, broccoli, cauliflower, Chinese cabbage, or fieldpea.
Summer Crop
Oriental pickling melon, Japanese cantaloup, jute, sweet potato, soybean, green manure crop, or native cabbage.
Source: Peter Kung, "Multiple Cropping in Taiwan, "World Crops, May/June 1969, pp. 128-130.

of water, furthermore, seem to have high priority; these include hydroelectric power, navigation, and salt water extrusion.[110]

Several studies of multiple cropping are now underway. The Department of Agricultural Economics at Kasetsart University has been examining systems involving corn and sorghum. A survey of over 50 farms in one region revealed that the cropping intensity was 168 in 1968 and 163 in 1969. The proportion of land double cropped seemed to change quite a bit from year to year; in part this was related to variations in amount of land rented.[111]

The Ford Foundation is sponsoring multiple cropping studies at Chiengmai University. The work started in January 1969 and through the fall of 1970 focused on the development of four prospective rotations, each requiring different levels of fertilization and management (**Table 12**). An effort is being made to develop labor-intensive rotations, but in some cases machinery is needed for seedbed preparation, seeding, and harvesting. Initial emphasis is being placed on vegetables, particularly those that may be processed. An economist is being added to the consultant staff to help appraise production costs and market potentials.[112]

A research project has also been initiated at the Chao Phya Regional Research and Extension Center at Chainat with the assistance of the Australian Government under the Colombo Plan. Other groups and nations working on projects which contribute, in various ways, to multiple cropping knowledge include FAO, Israel, and the University of Kentucky.[113]

VIETNAM

Double cropping in Vietnam has been traditionally concentrated in the Tonkin Delta in what is now North Vietnam, and the Central Lowlands in South Vietnam.

North Vietnam

In North Vietnam, about 2.17 million acres were reportedly double cropped in 1960.[114] This represented about 47% of total cultivated land or a cropping intensity of 147.[115] Of the double cropped area, a little over 3/4 was double cropped to rice and approximately 1/4 was devoted to a rotation of rice and some other crop. The government had an ambitious program to increase both the double and triple cropped area by 1965 but it is doubtful that much expansion took place.[116] Gourou, in a study of the Tonkin Delta first published in French in 1936, reported observing triple cropping of several types (rice-rice-dry crop; dry crop-dry crop-rice; rice-rice-rice) and in exceptional cases, four crops.[117] More recent examples of triple cropping in Thai Binh province have been noted by Chaliand.[118]

South Vietnam

In South Vietnam, about 621,000 acres of paddy land were double cropped in 1960. Considering the total cultivated paddy area, this represented a multiple cropping index of about 112.5.[119]

Of the double cropped area in 1960, about 543,600 acres (or 87.5%) were planted to a second crop of rice and 77,400 acres (or 12.5%) to other crops.[120] In 1966, about 568,000 acres of paddy were reportedly planted to a second crop of rice.[121]

Unlike North Vietnam, the major double cropped area was not found on delta land. Rather, about 80% of the area in 1960 was in the Central Lowlands (where the cropping index was about 166) and only about 20% was in the Southern Region (where the cropping index was about 103) which includes the Mekong Delta.[122]

A farm management survey of rice farmers during the 1968/69 crop year in the same two regions revealed the following proportion of cropped areas planted to a second crop of rice:

Region	No. Farms	Double Cropped
Central Lowlands	29	37.8%
Southern Region	113	5.5

Of the 113 farmers in the Southern Region, only 10 at the time were using IR-8 rice; however, 6 of the 10 produced a second crop.[123]

Within some portions of the Mekong Delta itself, the situation has evidently changed sharply in recent years. Sanson indicates that while less than 5% of the total Delta land was double cropped in the late 1950's, by 1966 about 41% of a sample group of farmers raised a second rice crop

Table 12. Experimental Multiple Cropping Rotations Chiengmai University, Thailand

Rotation No.	Cropping Sequence	Time Allocated to: Growing	Time Allocated to: Turnaround	Input Requirements: Nitrogen	Input Requirements: Management Skill
1	Rice-wheat-sorghum	320	45	High	Low
2	Rice-tomatoes-peanuts	310	55[1]	Intermediate	Intermediate
3	Rice-peas-soybeans-snapbeans	340	25[2]	Low	High
4	Rice-potato-sweet potato-sweet corn	370	-5[3]	High	High

[1]Requires more time to clean up field after the tomato crop, and peanut harvesting is slow.

[2]Pea plants will be pulled and carried out of field; area will be power tilled and planted to soybeans as fast as peas are removed. The same system will be used to remove the soybeans and plant the snapbeans.

[3]Sweet corn interplanted 25 days before sweet potato harvest.

Source: Letters from Dwight C. Finfrock, Project Specialist, Multiple Cropping Management, The Ford Foundation, Bangkok, September 4, 18, 1970.

and another 14% grew field vegetables. In addition, some farmers had a pure rotation of up to four garden vegetables[124]

The increase in cropped area in the Delta was due to greater use of fertilizer, increased availability of second crops with shorter growing seasons, and development of a water pump. The pump played a particularly important role in making the production of winter vegetables possible. Field vegetables (such as melons, squash, and tomatoes) were more easily grown on winter rice land than garden vegetables (onions, cabbage, lettuce, peppers and mint) which required land conversion. The greater cultivation of a second crop reportedly permitted"... a major increase in the level of family incomes.[125]

Subsequent programs in upland areas of the country have focused on introducing such second crops as grain sorghum.[126]

* * *

The information and data provided in this section have provided only an introduction to multiple cropping in the countries listed. Hopefully further details will become available for both these nations as well as those not covered. ■ ■

Notes

(1) Japan is included because its multiple cropping pattern is built around rice, the basic crop in many rotations in other nations in Asia. Limited data for the United States are presented in Appendix A.

(2) Shifting agriculture was discussed in Chapter I. Other variants include semipermanent cultivation involving five to ten years of continuous cropping followed by a fallow period of approximately equal length; such practices may be found on alluvial or flood plains such as along the Zambezi River or in the Kilombero Valley in Africa (Thayer Scudder, "Kariba Dam: The Ecological Hazards of Making a Lake," Natural History, February 1969, p. 70; R. Jatzold and E. Baum, The Kilombero Valley, Wellforum Verlag, Munich, Afrika Studien 28,1968, pp. 33-95). Some permanent multiple cropping may exist in such areas.

(3) N.D. Gulhati, Irrigation in the World: A Global Review, International Commission on Irrigation and Drainage, New Delhi, 1955, pp. 12.-15.

(4) H.P. Richter, "The Union of Burma, "in Agricultural Development in Asia (ed. by R. T. Shand), University of California Press, 1969, pp. 156,178.

(5) David E. Pfanner, "A Semi-subsistence Economy in Lower Burma," in Subsistence Agriculture and Economic Development (ed. by C.R. Wharton, Jr.), Aldine, 1969, p.-51.

(6) Malcolm MacDonald, Angkor, Jonathan Cape, London, 1958, p. 67; Maslyn Williams, The Land in Between: The Cambodian Dilemma, William Morrow, 1970, p. 37; Claire Sterling, "Mekong Project Points Up Superior Wisdom of Ancients," Washington Post, May 11, 1971, p. A18.

(7) Jean Delvert, "The Cambodian Peasant," Joint Publications Research Service (JPRS: 14,709), August 1962, pp. 446-468, 473-488. (Translation of Le Paysan Cambodien, Paris, 1961.)

(8) "Israelis Help Test Farm in Cambodia," Washington Post, July 1, 1970, p. F1.

(9) Noboru Yamada and Bhakdi Lusanandana, "Rice Production in the ADB Region," in Asian Agricultural Survery, Asian Development Bank, Manila, Vol. II, March 1968, p.26.

(10) Ibid.; D.H. Grist, Rice, Longmans, London, 1959 (3rd edition), p. 136. In the dry zones, irrigation is needed as a supplement during the Maha season and is virtually the complete source of water during the Yala season (P. Richards and E. Stoutjesdijk, Agriculture in Ceylon Until 1975, OECD, Development Center, Paris, 1970, p.47).

(11) S.H. Wittwer, "Maximizing Agricultural Production," Michigan Agricultural Experiment Station, Journal Article 4885, October 1969, p. 10 (based on a trip to Ceylon, August 1969).

(12) In much of the dry area, there is a tradition of using irrigation water only on rice (Richards and Stoutjesdijk, op. cit.).

(13) Wittwer, op. cit.

(14) Green manure crops (principally vetches grown in the Yangtze Valley) are included.

(15) Dwight H. Perkins, Agricultural Development in China, 1368--1968, Aldine, 1969, p.46. On a production basis, rice would of course rate much higher because of its relatively heavy yield.

(16) Based on information provided by Dr. Louis Erisman.

(17) Owen L. Dawson, Communist China's Agriculture: Its Development and Future Potential, Praeger, 1970, p. 224.

(18) "Mass Campaign for Agricultural Scientific Experiments in Full Swing in South China," New China News Agency, Kwangchow, October 15, 1969 (reported in "Survey of China Mainland Press," October 23,1969).

(19) Dawson, op. cit., p. 234.

(20) Perkins, op cit., p. 45; Foreign Agricultural Service Report No. HK0022 from Hong Kong, March 24, 1970, p. 6.

(21) Based on information supplied by Dr. Lewis Erisman. Also see Kang Chao, Agricultural Production in Communist China, 1949-1965, University of Wisconsin Press, 1970. pp. 166-167.

(22) Based on information provided by Marion Larsen.

(23) Report HK0022, op. cit., p. 6; "Chinese Agricultural Scientists Cultivate and Popularize Good Seeds," New China News Agency, Peking, December 11, 1969 (reported in "Survey of China Mainland Press," No. 4522); Lee Lescaze, "Fat Grain Harvest Rewards Red China's Agricultural Push," Washington Post, August 2,1970, p. A23.

(24) Statistical Abstract, India, 1961, 1968, Central Statistical Organization, Department of Statistics, New Delhi, pp. 30 and 56 respectively.

(25) S.S. Johl, "Mechanization, Labor Use, and Productivity in Indian Agriculture," Ohio State University, Department of Agricultural Economics and Rural Sociology, Occasional Paper No. 23, (1970 or 1971), p. 8.

(26) W.E. Henndrix, "India, Slow and Rapid Growth," in Economic Progress of Agriculture in Developing Nations, 1950-68, U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 59, May 1970, p. 151.

(27) "Pilot Project for Multiple Cropping," Report of the National Seminar on Multiple Cropping, New

Delhi, May 1970, p. 15.

(28) John W. Mellor, "The Evaluation of Rural Development Policy," in Developing Rural India: Plan and Practice (by Mellor, et al.), Cornell University Press, 1

(29) Ibid.

(30) "Rice Crop Proves Tanjore Program's Worth," Foreign Agriculture, March 4,1968, p. 7; James E. Wimberly, "Double-Crop Paddy in india; Mechanical Dryers Help Make it Work," World Farming, May 1968, p. 20; C. Muthiah, "The Agricultural Labor Problem in Thanjavur and the New Agricultural Strategy," Indian Journal of Agricultural Economics, July-September 1970, p. 20.

(31) Annual Plan, 1969-70, Government of India, Planning Commission, p. 48; Report, 1969-70, Government of India, Department of Agriculture, p. 21; A.A. Johnson and K. E. Eapen, "A Review of India's Package Program, " Foreign Agriculture, September 21, 1970, p. 11.

(32) John W. Mellor, "Prospects, Problems and Lessons" in Developing Rural India; Plan and Practice, op. cit., p. 351. In a recent study in the Punjab, noted earlier, the cropping index was projected to increase only on land irrigated by wells; the indexes for nonirrigated and canal irrigated lands remained the same (Martin H. Billings and Arjan Singh, "Farm Mechanization and the Green Revolution, 1964-1984, The Punjab Case," US/AID, New Delhi, April 22, 1970, p. 70).

(33) R.T. Gandhi, "Impact of High-Yielding Varieties on Cropping Patterns and Irrigation Policies", in 7th NESA Irrigation Practices Seminar, US/AID, Lahore, 1968, p. 99.

(34) Ibid., pp. 99, 101.

(35) D.M. Maurya, "Cheena- A Ideal Crop Between Rabi and Kharif," Indian Farming, March 1970, p. 25.

(36) M.S. Swaminathan, S.P. Bains, et al., "Latest Technology for Multiple Cropping-Principles, Practices and Problems," Report of the National Seminar on Multiple Cropping, New Delhi, May 1970, p. 70.

(37) P.N. Narula and D.P. Misra, "A Three-Crop Sequence for North Bihar," Indian Farming, August 1969. In the former rotation, TN-1 or Padma was planted for the first crop and IR-8 for the second. Another reference noted that Padma, though inferior to IR-8 in yield, has better grain quality and matures about two weeks earlier (K.S. Dargan, et al., "Performance of Jute and Rice Varieties in Multiple Cropping Programme," Indian Farming, March 1970.

(38) P.N. Arora and S.L. Pandey, "Intensive Rotations are Remunerative," Indian Farming, July 1969, p. 30.

(39) Vishnu Prasad, "A Profitable Crop Rotation for Farrukhabad," Indian Farming, November 1969, p.-28.

(40) New Intensive-Cropping Rotations in Tari, U.P. Agricultural University, Experiment Station, January 1968, pp. 2,12,17,49. More limited finacial data on other rotations in India are reported in Indian Farming, October 1970.

(41) Gandhi, op. cit., p. 99.

(42) S.S. Bains and K.S. Randhawa, "Multiple Cropping Pays in Delhi Union Territory," Indian Farming, October 1970, pp. 27-28.

(43) Mahendra Pal and S.K. Kaushik, "Multiple Cropping Multiplies Profits," Indian Farming, May 1969, pp. 29-30.

(44) Penny found multiple cropping practiced in three of eight villages surveyed in North Sumatra in the spring of 1962; the cropping indexes for the three were 102, 103, and 144 (David H. Penny, "The Transition from Subsistence to Commercial Family Farming in

Inter Cropping-maize sown in standing crop of mung (green gram)

North Sumatra," Cornell University, Ph.D. dissertation, June 1964, p. 89).

(45) Clifford Geertz, Agricultural Involution: The Process of Econological Change in Indonesia, University of California Press, 1963, p. 96 (citing the Dutch agronomist Tergast); D.H. Grist, Rice, Longmans, London, 1959 (3rd edition), p. 136.

(46) E.H. Jacoby, Agrarian Unrest in Southeast Asia, Columbia University Press, 1949 (1st edition), p. 38.

(47) Yamada and Lusanandana, op. cit., p. 26.

(48) Letter from John Shotwell, Agriculture Marketing Advisor, US/AID, Djakarta, August 21, 1970.

(49) Ibid.

(50) Letters from David H. Penny, The Research School of Pacific Studies, The Australian National University, Canberra, November 13,1970, March 16,1971.

(51) World Bank, International Development Association, Annual Report 1970, p. 10; Asian Development Bank, Annual Report for 1970, pp. 29-30.

(52) Penny, op. cit. (1970-71).

(53) Letters from C.S. Stephanides, Agricultural Attache, American Embassy, Tehran, August 18 and September 3,1970.

(54) Letters from John Freivalds, Economist, Development and Resources Corporation, Sacramento, September 9, October 26,1970. The development project is described by Lee Griggs in "Oil and Water Rebuild an Ancient Land," Fortune, November 1970, pp. 90-96.

(55) H. Charles Treakle, The Agricultural Economy of Iraq. U.S. Department of Agriculture, Economic Research Service, ERS-Foreign 125, August 1965, p. 30.

(56) Leonard M. Cantor, A World Geography of Irrigation, Praeger, 1970, p. 136.

(57) Takane Matsuo, Rice and Rice Cultivation in Japan, Institute of Asian Economic Affairs, Tokyo, 1961, p. 81.

(58) Joseph R. Barse: Japan's Food Demand and 1985 Grain Import Prospects, U.S. Department of Agriculture, Foregin Agricultural Economic Report No. 53, June 1969, p. 41; "Changed Rice Policies Could Transform Japan's Farming", Foreign Agriculture, February 9,1970, p.5.

(59) Shujiro Sawada, "Technological Change in Japanese Agriculture: A Long-Term Analysis," in Agriculture and Economic Growth: Japan's Experience (ed. by Ohkawa, et al.), Princeton University Press/University of Tokyo Press, 1969, p. 152.

(60) Calculated from official data provided by Dr. Yujiro Hayami, Faculty of Economics, Tokyo Metropolitan University, September 3,25,1970.

(61) Matsuo, op. cit., pp. 81, 177. Also T. Matsuo, Rice Culture in Japan, Yokendo, Ltd., Tokyo, 1955, pp. 28, 37.

(62) William Gasser of the Economic Research Service was of assistance in the preparation of this section.

(63) Jin Hwan Park, An Economic Analysis of LandDevelopment Activities in Korea, with Special Reference to Upland Development Programs in 1962-1967, Seoul National University, Development of Agricultural Economics, November 1969, pp. 10, 86.

(64) Young Kun Shim, Economic Analysis of Double Cropping in Paddy Fields, Seoul National University, College of Agriculture, Code No. 66-26, 1967 (distributed in 1969), pp. 5,26. Shim's survey of 1,258 farms also indicated a lower proportion of paddy land double cropped in 1967 (33%) than did the official figures (47%).

(65) William R. Gasser, et al. Planning Korea's Development: Analyses and Recommedations for the Third Five Year Plan, U.S. Department of Agriculture, Foreign Economic Development Service, FEDS Field Report 5, August 1970, pp. 23-27.

(66) Letter from Donald R. Mitchell, Deputy Chief, Agriculture, US/AID Mission to Laos, Vientiane, April 23, 1971. A recent Asian Development Bank report placed the figures slightly higher: 1967/68, 3,700 acres; 1968/1969, 5,000 acres (of which 1,100 were in the Vientiane Plain).

(67) "ADB Approves Loan and Technical Assistance for the The Ngon Project in Laos," Asian Development Bank, Manila, News Release No. 3/70, March 10,1970.

(68) T.L. Jones et. al., An Evaluation of the Agricultural Development Organization of Laos, Ohio State University, Department of Agricultural Economics, AFC Research Publication 130, 1969, p. 41.

(69) Mitchell: op. cit.; letter, June 1,1971.

(70) Letter from William Horbaly, Agricultural Attache, American Embassy, Beirut, April 16,1971.

(71) Foreign Agricultural Service Report No. MY 9035 from Kuala Lumpur, October 31, 1969, p.2.

(72) Letter from Dale K. Vining, Agricultural Attache, American Embassy, Kuala Lumpur, March 12,1971.

(73) "Muda River Project," World Crops, March/April 1969, p. 14.

(74) Dale K. Vining, "West Malaysia's Rice Irrigation Project," Foreign Agriculture, July 14,1969, pp. 9-10; Foreign Agricultural Service Report No. MY0015 from Kuala Lumpur, Septmber 17,1970.

(75) "International Letter," National Association of Land Grant Colleges and Universities, No. 67, December 29, 1970, pp. 11-12.

(76) Kieran Broadbent, "Case for Irrigation," Far Eastern Economic Review, December 26, 1968, p. 738.

(77) Department of State Airgram A-3 from Kuching, January 10,1969.

(78) "Country Progress Report: Nepal," 7th NESA Irrigation Practices Seminar, US/AID, Lahore, 1968, pp. 68,71; letter from Raymond E. Fort, Chief, Food and Agriculture Division, US/AID, Kathmandu, March 10,1971.

(79) The indexes as reported in some other studies varied from those reported here. Generally they were higher. Data reported by Ahmad indicate an index of 139 in 1944-45 (An Economic Geography of East Pakistan. Oxford University Press, Karachi, 1958, p. 168). In a survey of 711 cultivators in 1958-59, the cropping index was reported to average 133.9 (Survey Report on Cropping Patterns in Selected Districts ofPakistan, Ministry of Food and Agriculture, Department of Agricultural Economics and Statistics, Rawalpindi, Survey Series 2, February 1962, p.7). Data used by Revelle and Thomas suggest an average index of 144 from 1960-65 ("Population and Food in East Pakistan," Harvard Center for Population Studies, Fall 1969, Table 1). Cantor, without mentioning a specific year, also suggests an index of 143 (A World Geography of Irrigation, Praeger, 1970, p. 128). On the other land, statistics provide in a master plan for the East Pakistan Water and Power Development Authority show indexes 1 to 3 points lower for the 1948-49 to 1956-57 period (Master Plan, International Engineering Co., San Fran-

sisco, Supplement B, December 1964, p. IV/3), while another source suggests that double cropping is carried out on 25% of the land and triple cropping on 5% ("Country Progress Report: Pakistan," 8th NESA Irrigation Practices Seminar, US/AID, Kabul, 1970, p. 67).

(80) "Survey Report on Spread of New Agricultural Technology to Small Farms in Pakistan," Farm Management Research in Pakistan (Ministry of Agriculture and Works, Planning Unit), October 1969, p.14.

(81) Letters from Jerry B. Eckert, Agricultural Planning Advisor, The Ford Foundation, Lahore, March 1, 1971, April 28,1971.

(82) Survey Report on Cropping Pattern and Crop Intensities in Selected Districts of Pakistan, Ministry of Food Agriculture, Department of Agricultural Economics and Statistics, Rawalpindi, Survey Series 2, February 1962, p. 3.

(83) Mahmoodur Rahman, Costs and Returns: Ecnomoics of Winter Irrigated Crops in Comilla, 1965-66, Comilla, March 1967, pp. 1,2, 125. Also see A.F. Raper, Rural Development in Action, Cornell University Press, 1970, pp. 139-152, 215.

(84) Nicolaas Luykx, "... Rural East Pakistan," in Some Issues Emerging from Recent Breakthroughs in Food Production (ed. by K.L. Turk), Cornell University, 1971, pp. 162-163.

(85) Survey Report... op. cit. (1962), pp. 18, 21. Also see Water and Power Resources of West Pakistan, Vol. II, Johns Hopkins Press, 1969, pp. 52-58.

(86) Hiromitsu Kaneda and Mohammed Ghaffar, "Output Effects of Tubewells on the Agriculture of the Punjab: Some Empirical Results," Pakistan Development Review, Spring 1970, p. 71.

(87) Ibid., pp. 71-73.

(88) Census of Agriculture 1960, Bureau of Census and Statistics, Manila (as reported by Cristina Crisostomo, et al., "The New Rice Technology and Labor Absorption in Philippine Agriculture," in Rice Policy Conference: Current Papers from the Department of Agricultural Economics, International Rice Research Institute, May 9-14, 1971, p. 15, Table 8).

(89) E.H. Jacoby, Agrarian Unrest in Southeast Asia, Columbia University Press, 1949 (1st edition), p. 177. The 1938 figure was based on a report by Pelzer and is found in fn. 16.

(90) Yamada and Lusanandana, op. cit., p. 26. Another source places the irrigated paddy area under a second crop in 1965/66 as 697,000 acres (Shigeru Ishikawa, Agricultural Development Strategies in Asia: Case Studies of the Philippines and Thailand, Asian Development Bank, Manila, 1970, p. 16).

(91) Horst and Judith von Oppenfeld, et al., Farm Management, Land Use and Tenancy in the Philippines, University of the Philippines, Central Experiment Bulletin 1, August 1957, pp. 37, 119 (as cited by Crisostomo, et al., op. cit., p. 16).

(92) E.R. Bernal, "Unit Requirements, Costs and Returns for Producing Palay and Secondary Crops in Central Luzon, 1962-1963," The Philippine Agriculturist, September-October 1964, pp. 203-232. This index is particularly high because the farms involved all grew some secondary crops.

(93) Moises L. Sardido, "Income Distribution Patterns of Rice Farms in Bico," International Rice Research Institute (Saturday Seminar), December 1969, Tables 9 & 12 (cited by Crisostomo, et. al., op. cit., p. 16, Table A-14).

(94) N.R. Deomampo, et al., "The Effects of Cropping Patterns on Farm Capacity," The Philippine Agriculturist, June 1969, pp. 17-27; E.M. Gonzales, "The Economics of Crop Diversification on Upland Farms in Balete, Tanauan, Batangas," University of the Philippines, undergraduate thesis, 1969 (as cited by Crisostomo, et al., op. cit., pp. 16, 17).

(95) Crisostomo, et al., op. cit., pp. 17-19.

(96) C.L. Luh, "Report on Vegetable Production Survey in Southeast Asian Countries," Seminar on Food Problems in
Asia and the Pacific,
Honolulu, May 1970, p. 11.

(97) Richard Bradfield, "Increasing Food Production in the Tropics by Multiple Cropping," in Research for the World Food Crisis (ed. by Daniel G. Aldrich, Jr.), American Association for the Advancement of Science, Publication No. 92, 1970, pp. 229-242.

(98) Chien-pan Cheng, "Multiple Cropping Practiced on Paddy Field in Taiwan," Joint Commission on Rural Reconstruction, Taipei, April 1970, p.11.

(99) T.H. Lee, "Agricultural Diversification and Development," SEADAG Paper No. 71-2 (The Asia Society, New York), p. 16.

(100) T.H. Shen, Agricultural Development on Taiwan Since World War II, Comstock Publishing Associates, 1964, pp. 156-157.

(101) Cropping systems are also summarized in Raymond P. Christensen, Taiwan's Agricultural Development: Its Relevance for Developing Countries Today, U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 39, April 1968, p. 50.

(102) Peter Kung, "Mualtiple Cropping in Taiwan," World Crops, May/June 1969, p. 129; Cheng, op. cit., pp. 7-8

(103) Cheng, op. cit., p. 9.

(104) T. H. Silcock, "Thailand", in Agricultural Development in Asia (ed. by R. T. Shand), University of California Press, 1969, pp. 125-126.

(105) Letter from Delane E. Welsch, Agricultural Economist, The Rockefeller Foundation, Bangkok, January 7, 1971.

(106) Shigeru Ishikawa, Agricultural Development Strategies in Asia: Case Studies of the Philippines and Thailand, Asian Development Bank, Manila, 1970, p. 84 (fn. 96).

(107) C. L. Luh, "Report on Vegetable Production Survey in Southeast Asian Countries," Seminar on Food Problems in Asia and the Pacific, Honolulu, May 1970, p. 12.

(108) Ishikawa, op. cit., pp. 75 (fn. 82), 82.

(109) Silcock, op. cit., (1969), pp. 134-135.

(110) W. Van der Kevie, "Soil Landscapes and Potential Land Use in the Central Plains." Thai Journal of Agricultural Science, January 1970, pp.1-12.

(111) "Multiple Cropping Systems which Included Corn and Sorghum in Amphoe. Phayuha Khri, Changwat Nakhon. Sawan, in 1968 and 1919." Kasetsart University, Department of Agricultural Economics, 1970. Also see Brook Greene, Rate of Adoption of New Farm Practices in the Central Plains, Thailand, Cornell University, Department of Agricultural Economics, Occasional Paper No. 41, July 1971.

(112) Letters from Dwight C. Finfrock, Project Specialist, Multiple Cropping Management, The Ford Foundation, Bangkok, Sep-

(Continued on page 138)

BACK NUMBERS

BACK NUMBERS

Small farm machines are expected to promote agricultural mechanization. But, needless to say, people must improve a field condition to introduce them.

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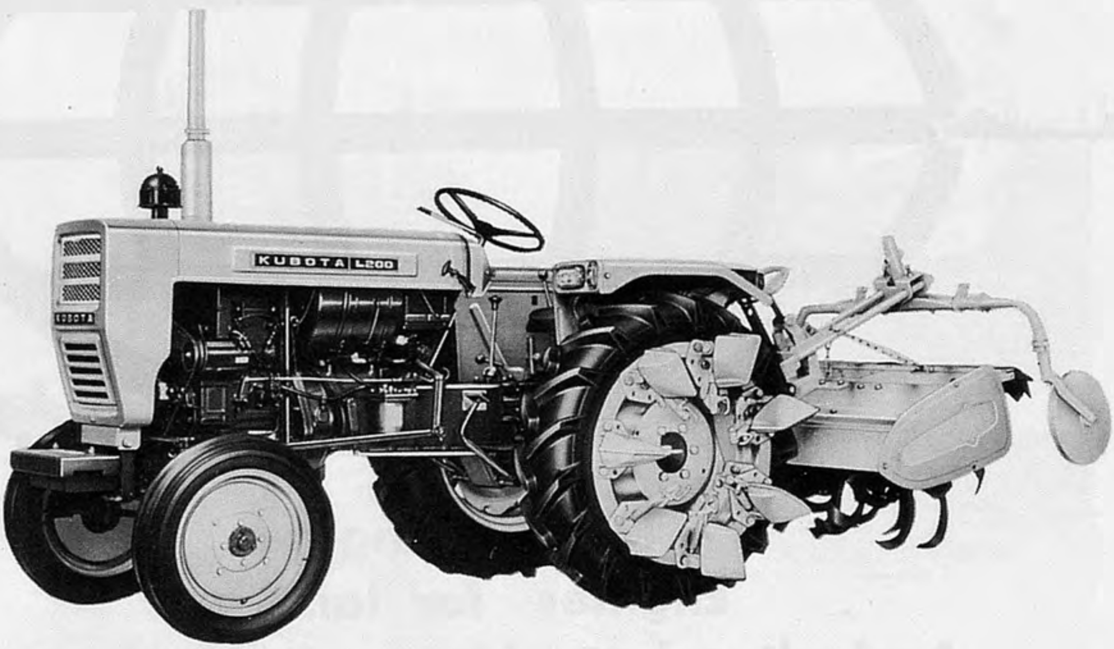

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Over 50 years experiences in agricultural machinery production, we have established world wide market as well as domestic market.
Through the marketing process, we have studied and researched many markets with ISEKI products on important and complicated problems in varied cultivation method, climate, soil conditions, kinds of plantation and concerning social factors.
And we have ever been endevouring to develop most suited machines with experiences and new ideas gained through market study and research.
Especially in recent years we have mainly specialized with full mechanization of rice cultivation which is one of the most popular and fundamental crops among Asian countries, of course, including Japan.
And now we are very pleased to be able to introduce you our completely full range of agricultural machines for integrated mechanisation of rice production, that is, from planting through harvesting to finishment.
We always hope that we will be able to contribute in agricultural consolidation and enlargement of productivity through the agricultural mechanization.

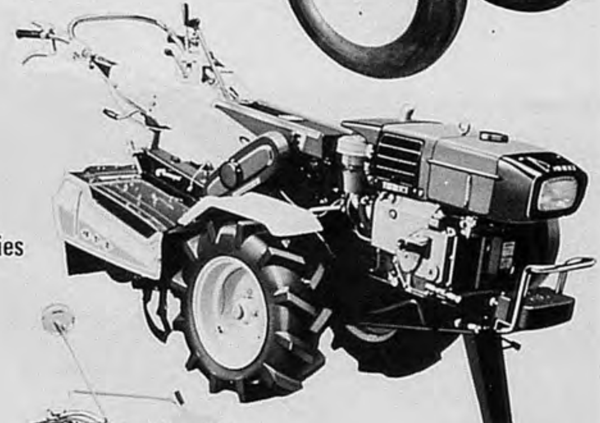
ISEKI AGRICULTURAL MACHINERY MFG. CO., LTD.
Overseas department
1-3, Nihonbashi, 2-chome, Chuo-ku, Tokyo 103, Japan

agricultural
bring

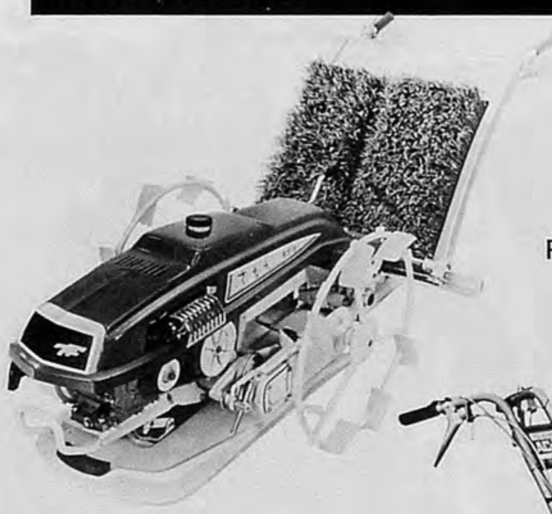
LET ISEKI PLAY THE MAIN RO

ISEKI's mechanization system of rice culture

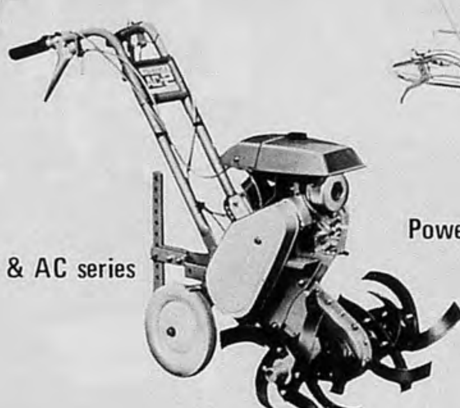
4-wheel tractor TS series



Power tiller KA series



Rice transplanter

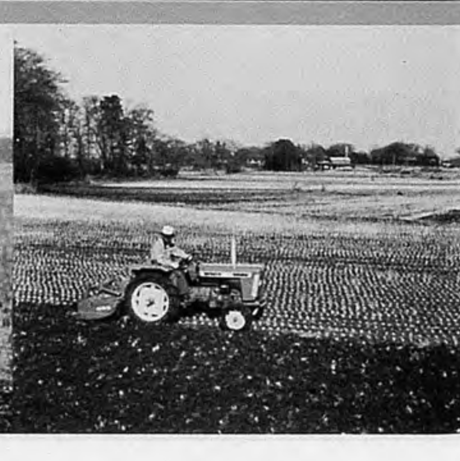


Powertiller KC & AC series

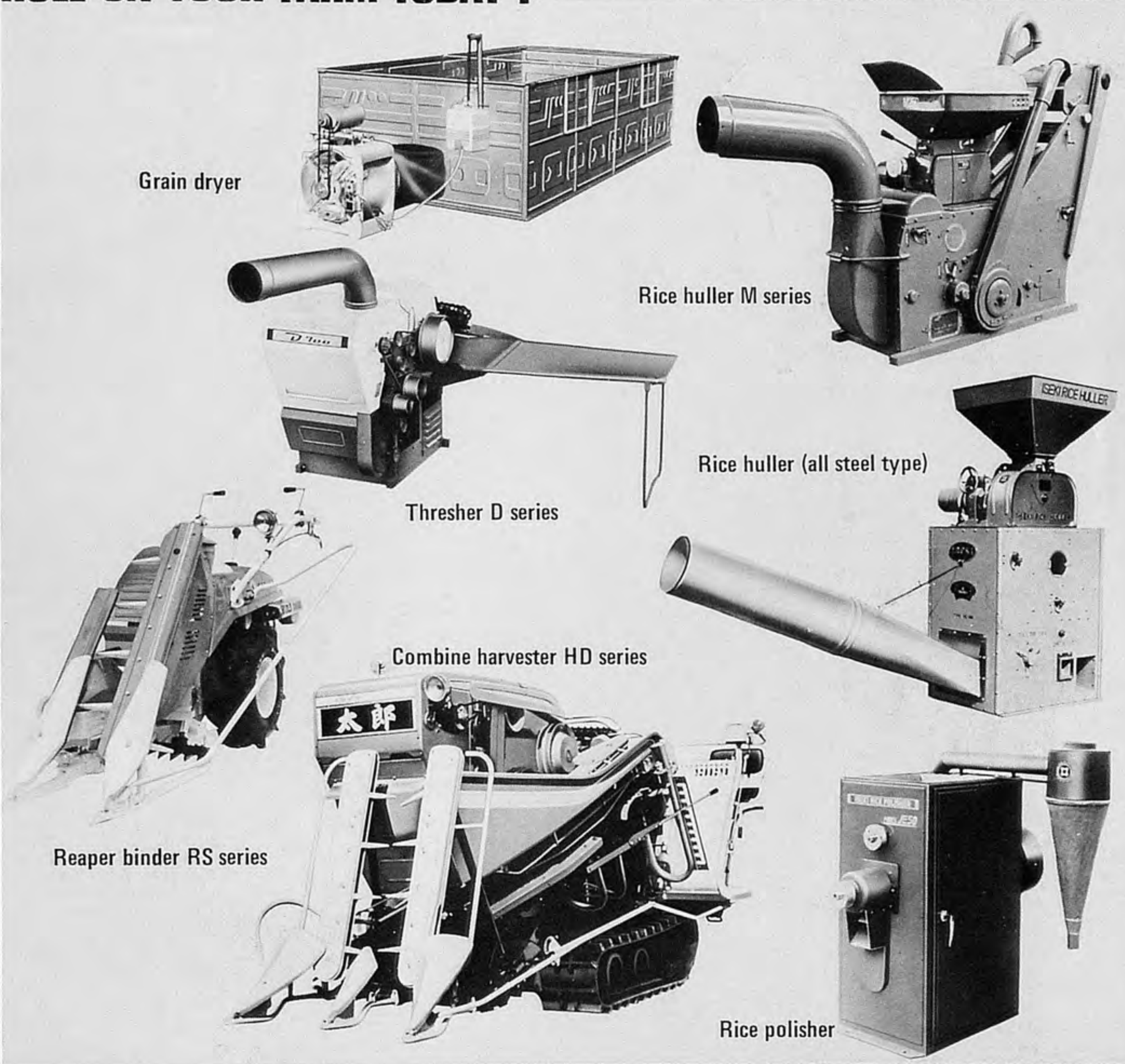
Power tiller KS series

Rice transplanting

Rotary tilling



IN ROLE ON YOUR FARM TODAY !



Harvesting (reaper binder)

Harvesting (combine harvester)