FARM MECHANIZATION IN EAST ASIA

edited by
HERMAN SOUTHWORTH

A/D/C

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PREFACE

Constant changes in technology are an essential part of the process of "getting agriculture moving". Technology here refers to biological, chemical and mechanical innovations.

Biological innovation (such as the use of high-yielding varieties) can increase productivity. Chemical innovation (such as the use of insecticides or pesticides) can reduce waste or loss. Farmers operating on small area of land do not need much persuasion in accepting these two types of innovations because of their favorable benefit-cost ratios.

Making use of mechanical innovations on small farms is often a much more complex matter, involving economic and social as well as technical problems. Farm machinery must be well-designed and durable for multi-purpose operations. It must be economically profitable. It must also fit the social and economic structure of the families, farms, and communities that are expected to use it. It must, in other words, be socially acceptable under the local institutional arrangements.

Many biological and chemical innovations can be applied without other major changes in the way a family farms or lives. Not so with mechanical innovations, which usually require heavy capital investment. They are closely associated with both individual and national problems of income distribution and employment. Experience shows that farmers in the more productive areas are the early innovators of mechanization, which leads to imbalance of income growth within the farm sector. Moreover, mechanization can be accompanied by new and expanded employment opportunities or it can create serious seasonal unemployment.

Research interests in farm mechanization center on four major aspects: the needs of the individual farmer, the needs of the farming community, the role of agricultural machinery industries, and the requirements of government policies.

All four aspects are interrelated or complementary to each other. For instance, the factors considered as "given" or exogenous in farm management analysis are, in effect, policy variables in program planning—e.g., the prices at which it will pay farmers in typical situations to invest in certain machines become guides to pricing policies or goals in mechanization programs.

For more than three decades, Japan has been demonstrating ingenuity and accomplishment in introducing mechanization on small farms. More recently, due to rapid expansion of industry, Taiwan and Korea have also begun to realize labor shortages in rural areas and have begun to mechanize their agriculture. They thus have an understandably strong desire to study and learn about the Japanese experience and to find out whether they should follow Japan's path or whether they must build different models to achieve equally impressive results without serious economic and social repercussions.

This is the second A/D/C East-Asian Regional Workshop. The first, on Agricultural Marketing, met in Taipei in August 1969.

This most recent Workshop, organized with the cooperation Japan's Overseas Agricultural Development Foundation, was held at Tokyo from 23 to 31 August 1971. Twenty participants from the three East Asian countries were invited, and the group also included one participant from Malaysia and one from Thailand, along with one observer from the Asian Productivity Organization. Each of the 22 participants prepared and presented a paper. A/D/C also sent four staff members to take part in the Workshop, and Herman Southworth and Shao-er Ong made a major contribution to its planning.

Of the 9-day meeting, three days were spent in field trips to visit mechanized farms, agricultural settlement projects, and the Kubota and Yanmar agricultural machinery factories.

Mr. Motonaga Ohto, managing director of the Overseas Agricultural Development Foundation, gave untiring help in arranging the meeting place, field trip, and social events. His efforts also brought generous cooperation from the Japan Agricultural Machinery Manufacturing Association in sharing the Japanese experience in farm mechanization.

Because of the potential value of these papers in stimulating inter-country exchange of information and ideas, A/D/C has made use of a grant to it from the International Development Research Centre of Ottawa, Canada, to make possible their publication and distribution. In generously providing such support, the Centre does not review the material published nor pass judgment on the ideas presented. It hopes, as does A/D/C, that making this material available will encourage further informed discussion among teachers and students, research workers, farmers, machinery manufacturers, and policy makers interested in agriculture in Asia.

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FACTS AND PROBLEMS OF FARM MECHANIZATION: THE CASE OF KOREA

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A large farm population relative to the limited area of cropland has been the basic characteristic of factor combination in the organization of Korean agricultural production.

Often it has been said that the agricultural sector has a large reservoir of labor for which the marginal product is zero or near to zero. In fact, in the winter most of the family labor on general crop farms has been idle due to limited employment opportunities within and outside of the farm. In the peak season, however, the stock of farm labor has been fully employed in farming operations under the existing farm organization, and shortage of family labor has been an important constraint upon introduction of labor-intensive enterprises.

Thus, even in the early stage of urban-industrial development in Korea, the rural labor market has had a problem of shortage amidst abundance.

Because of limited economic feasibility of introducing expensive farm machinery and the shortage of family labor in the peak season, the family labor on small farms was as busy with their own field work as on large farms, and operators of large farms had to worry about getting enough hired labor for timely field operations. Often, a permanent employee lived with the family on large farms to assure having hired labor when it was needed. These facts indicate that the extent of underemployment of farm labor in the traditional economy of Korea varied with the season, and there was a labor shortage in the peak season.

Out-migration of younger workers

The rapid growth of the urban-industrial sector in the last decade has brought significant changes in the relative prices of input factors in agricultural production. Especially, wages for hired labor have increased rapidly due to increased outflow of farm labor.

The outflow of farm labor has been selective among age groups. Young people have constituted the major portion of the rural out-migration in recent years.

Rural youngsters seem to put a lower value on the opportunity cost of leaving the farm than do the older farmers. At the same time, rural youngsters feel that the expected returns from urban jobs for the rest of their lives will be higher than for older farmers. Unmarried farm boys and girls or young couples who are not yet committed to becoming farm operators feel freer to leave farms than do the older generation.

In most farm areas the total number of males and females in the age levels from 15 to 35 years old was significantly smaller in 1970 than in the mid-1960s (see Table 1). The outflow rates of young workers were particularly high in areas where rice mono-culture predominated, with limited employment opportunities other than rice production, and in remote mountainous regions where crop land is used for subsistence production, with limited opportunities for earning cash income from either farm or non-farm activities.

Large cities, especially Seoul and Pusan, have been the major pulling centres for the outflow of rural labor. Cities closer to home but with low growth of employment opportunities have not attracted significant numbers of rural workers. The over-concentration of population in Seoul is increasing the problems of regional gap in the modernization process of the traditional economy. Decentralization of urban-industrial activities is needed to accelerate rural development.

As urban-industrialization has speeded up the outflow of rural labor, there are different time lags in changes of the stock of family labor on individual farms, the total farm population, the total number of farm households, and the average size of farms. An outflow of youngsters immediately affects the stock of young workers on individual farms. The reduced labor force on individual farms does not appear clearly in the statistics of total farm population, which increased at a decreasing rate until the mid-1960s and then leveled off in the late 1960s (see Table 2).

Table 1. Percentage Change of Male Population in the City of Pusan and in South Kyongsang Province, Korea, 1964 to 1968.

City or country	Age group 15–19	20–24	25–29	30–34	35–39	All male population
	percentage change, 1964 to 1968					
Pusan city	13.1	10.8	21.7	29.6	16.1	11.7
Ilsan city	27.2	34.7	72.9	99.7	84.7	41.6
Masan city	21.4	15.7	17.2	25.2	19.6	9.8
Jinju city	4.5	10.6	8.7	29.6	17.1	12.1
Jinhae city	13.5	6.2	−4.0	9.2	40.9	11.2
Chungmu city	−1.6	3.2	−1.2	5.3	6.8	−1.0
Keuje city	−3.2	1.7	−18.8	−2.6	−1.0	−3.2
Namhae city	−8.0	1.5	−16.1	−14.0	1.9	−2.9
Tongyoung gun	−5.2	1.0	−11.0	−4.4	3.2	0.1
Samchonpo city	−2.7	−0.1	−7.9	15.0	9.8	2.0
Kimhae gun	3.4	−3.9	−12.0	−11.9	5.3	−4.8
Dongnae gun	4.6	−6.4	−18.2	2.3	1.4	−4.1
Changwon gun	1.7	−8.1	−20.0	−10.3	1.2	−6.6
Gosung gun	−3.3	−8.8	−23.7	−6.7	−3.0	−7.2
Sachon gun	2.4	−8.8	−17.0	−1.3	−0.8	−2.9
Changyoung gun	3.9	−10.5	−22.1	−13.6	4.7	−5.5
Hadong gun	1.5	−12.7	−18.8	−8.6	1.8	−3.0
Milyang gun	1.8	−13.2	−19.6	−10.3	−3.6	−5.7
Ulju gun	−2.1	−13.4	−20.2	−10.2	4.6	−7.6
Jinyang gun	6.7	−16.6	−25.1	−12.9	−0.7	−7.2
Hamyang gun	−6.6	−18.4	−22.4	6.9	−1.9	−2.9
Keochang gun	1.6	−20.3	−25.8	−7.5	8.5	−4.8
Haman gun	−4.7	−20.5	−28.3	−11.4	8.1	−6.8
Sanchung gun	−14.8	−20.7	−26.7	−8.2	6.0	−7.3
Hapchun gun	−2.4	−20.8	−25.4	−10.0	2.6	−7.2
Euryong gun	−6.6	−22.8	−24.9	−14.5	1.3	−6.2
Yangsan gun	0.2	−11.8	−16.0	−5.4	14.1	−5.1
For the province*	0.9	−7.7	−14.1	−0.8	7.6	−2.1

* Excludes Pusan city.

Table 2. Total Farm Population, Farm Households, and Area of Cropland, Korea, 1959–70.

Year	Farm households	Farm population	Crop land
	(1,000 farms)	(1,000 persons)	(1,000 ha.)
1959	2,267	14,126	2,033
1960	2,350	14,560	2,050
1961	2,327	14,509	2,050
1962	2,469	15,097	2,080
1963	2,416	15,266	2,097
1964	2,450	15,553	2,189
1965	2,507	15,812	2,275
1966	2,540	15,781	2,312
1967	2,587	16,078	2,331
1968	2,579	15,908	2,338
1969	2,546	15,589	2,330
1970	2,448*	14,455*	2,153*

* Preliminary report from 1970 agricultural census. The sharp decreases in 1970 census data from statistics in previous years may be due to differences in definition of farm population.

The increasing mobility of rural youngsters has had very little effect on the total number of farm households and average size of farms. Therefore, if we look closely at the supply and demand situation of family labor on individual farms we become immediately aware of the increasing shortage of labor. However, if we look at the over-all statistics of cropland, number of farm units, and farm population, we will be impressed by the surplus labor force in the agricultural sector.

If the growth rate of the non-farm sector in the 1960s continues throughout the 1970s, the total farm population will decline significantly. However, the decline in farm population is not likely to bring significant changes in the total number of farm units and average size of farms in the immediate future. Because the outflow of rural labor is highly selective with respect to age, so that young persons in a family leave but an out-migration of an entire family seldom occurs, the total number of farm units will remain about the same for a considerable time.

Effect of changes in the land market

In the long run, we would expect that the number of farm units will be reduced as present farm operators retire, and that the size of farms in terms of cultivated land will be enlarged. This long-run projection may be correct in some agricultural regions, such as rice mono-culture areas and remote mountainous regions where non-farm employment opportunities are limited. However, in the farming areas near to urban-industrial centres or where transportation facilities are well developed, the average size of farm is not likely to be enlarged.

Some large-size commercial farms producing livestock products and special cash crops will be established, but the increasing scarcity of cropland in these areas will discourage the enlargement of existing farms. The shifting of cropland to urban-industrial uses is causing a rapid increase in land prices.

In the farm areas near to urban-industrial centres the prices of land are often increasing more rapidly than the current interest rates, and land is too expensive to purchase for agricultural uses. In localities suitable for establishing new commercial farm units, the difficulty of purchasing a large enough area of cropland in a single piece is becoming the major constraint upon scale expansion. The existing farmers in such localities are unwilling to sell their whole property, though they may sell a part of their land holdings.

Thus, the rapid growth of the urban-industrial sector brings impacts on both labor and land markets in agricultural production.

In the labor market, wages for hired labor have increased more rapidly than the productivity increase of hired labor (see Table 3). Hence, without introduction of labor-saving technology, the scale expansion of existing family farms is discouraged.

In the land market, the demand for land for urban-industrial uses is affecting the price of cropland, and the difficulty in purchasing a parcel of cropland in one locality at a suitable price for agricultural production discourages enlarging farm

Table 3. Farm Prices of Rice, Hired Labor, and Fertilizer, Korea, 1961–70.

	Prices at farm level			Real price index (1965 = 100)		
Year	Rice	Adult hired labor	Nitrogen fertilizer	Rice	Adult hired labor	Nitrogen fertilizer
	(won/100 liters)	(won/day)	(won/45 kg)			
1961	1,626	106	392	98.8	93.8	111.3
1962	1,926	115	397	95.7	92.9	103.0
1963	2,710	143	385	127.3	112.0	83.0
1964	3,422	199	311	117.2	99.0	76.5
1965	3,210	221	688	100.0	100.0	100.0
1966	3,386	256	688	97.0	106.4	91.9
1967	3,730	307	585	100.2	111.0	73.4
1968	4,390	381	585	109.3	137.9	67.9
1969	5,435	463	651	126.6	156.0	70.8
1970*	5,565	530	651	122.2	170.0	66.7

* —Monthly Statistics of National Agricultural Cooperative Federation.

size. These characteristics of the labor and land markets imply an increasing need for capital to substitute for labor and land in agricultural production. Also, it suggests that the scale of farm mechanization in the Korean agricultural setting must fit the existing farm size. In other words, mechanization is needed with the present size of farms.

Farm management aspects

Economic justification for introducing labor-saving technology under the existing farm organization is found also from a farm management viewpoint. In order to increase cash income and to meet the demand for foods in the economy, the managing of a family farm will increasingly have to shift towards intensification and diversification in use of farm resources. To increase rice production, yield must be increased by intensification and additional enterprises will be added for more productive use of farm resources on mono-culture rice farms.

In most cases, intensification and diversification require a larger amount and better quality of labor input per farm. In other words, in transforming traditional agriculture to commercial production to meet the needs of the growing economy, the labor demand on existing farms increases. But the supply of family labor is not meeting the increasing demand. Improvement in rural education has significantly raised the quality of rural labor. But education alone is not sufficient to increase output per labor-hour without accompanying inputs complementary to labor.

In rice production most field work is done by manual labor as it was five or ten years ago. Increasing use of biochemical inputs has raised yields and output per labor-hour. However, wages for hired labor have increased much faster than the increase in labor productivity. For sustained growth of rice yield, which has already reached a high standard, farm machinery is being requested as a complementary input for effective use of biochemical inputs.

Land tenure and economies of scale

Since the degree of capital-labor substitution in rice production is about the same for both large and small farms, economies of scale are not great. The number of rice farms of more than three hectares of paddy land has increased rather slowly compared to other types of farms. The legal constraint setting an upper limit on land holdings of three hectares of cultivated land, under the Land Reformation Law (1950), has been an institutional factor restricting the scale expansion of crop farming. In the revised Land Tenure Law which is now under study in the National Assembly it is proposed to release the upper ceiling on land holdings.

It has often been argued that the factors restricting scale expansion in rice farming are found in farm management, and that the legal upper limit is not a serious constraint. Rice cultivation on both small and large farms is done mainly by manual labor, and the proportion of hired labor input increases as the area of operated land increases.

Since the wages for hired labor have increased more rapidly than the productivity of hired labor, the economic incentives for scale expansion are discouraged. Therefore, local availability of farm machinery of good quality at low prices is essential for scale expansion in rice farming, if the release of the legal upper limit on land holdings is to have any effective consequence.

Rise in living standards

As the urban-industrial sector grows rapidly, the inconveniences of rural life and the slow progress of labor efficiency in farm work are undermining the labor discipline of farm boys and girls, who are attracted by urban life.

Rural young people are unwilling to live under kerosene lamps; they want electric lights. They want more efficient means for transporting both people and goods. They put high prestige values on new machinery.

Need for mechanization

Viewing the prospects of economic development in Korea, it is likely that the outflow of rural young people will continue in the 1970s without significant change in the average size of farm. And the wage rates for hired labor in agricultural production will continue to increase. Intensification and diversification of farm management for market production will proceed further.

Hence, the demand for farm machinery will increase rapidly in the 1970s, not so much for scale expansion of agricultural production as for intensification on existing farms.

Heavy equipment is increasingly used for land development (paddy rearrangement, hill-land development for agricultural uses, road building) and for development of water resources. Land and water resource developments are undertaken mainly as public programs, and heavy equipment is owned mostly by the agencies responsible for public development programs. Few empirical studies have been made on effective use of heavy equipment for land and water resource development. Also, little is known about the future demand for heavy equipment for rural development purposes.

At the farm level, substitution of engine power for animal and human power is increasingly needed for various field work and for rural transportation of both outputs and inputs.

Summary

The above discussion can be summarized as follows:

(1) In the traditional economy, where most people were engaged in semi-subsistence agriculture, farm labor was relatively abundant, but there was a shortage of family labor in peak seasons on most crop farms. The shortage was overcome by using hired labor supplied from within the agricultural sector.

(2) As the urban-industrial sector has grown rapidly, the supply of hired labor in the agricultural sector has been reduced by rapid outflow of younger workers. The cost of hired labor in agricultural production has increased rapidly while labor productivity has not increased significantly.

(3) As the urban-industrial sector continues to grow rapidly, farm management is shifting increasingly toward intensification and diversification for commercial production, which requires a larger labor input per farm unit.

(4) In accord with the increasing participation of the government in rural infrastructure development, the demand for heavy equipment has increased rapidly. Economic use of heavy equipment for rural development programs is a new research area.

(5) At the farm level, substitution of engine power for animal and human power will take place rapidly in the 1970s even

though the size of farm remains the same.

Constraints upon Mechanization

Until the mid-1960s public policies paid little attention to farm mechanization in Korea; programs for water supply and biochemical inputs were the major policy concerns for agricultural intensification. The need for farm mechanization has emerged rapidly in the late 1960s.

By now there is a substantial gap between need and practice in farm mechanization. In spite of an increasing shortage of farm labor, the substitution of capital for labor has been inelastic. While there is much talk about farm mechanization, only a small fraction of farmers are using improved machinery.

Investigation of the reasons for the inelastic substitution of capital for labor on farms should have research priority.

Among the numerous constraints, the following are important: size of farm and land tenure, land fragmentation, biological characteristics of rice cultivation, relative prices and quality of machinery, farmers' lack of knowledge of machine operation, output prices, and farm income. The situation we face in Korea with respect to some of these variables will be investigated briefly in this section.

Size of farm and land tenure

As discussed in the previous section, the problem of labor shortage on family farms in Korea is emerging not because farms are getting larger but because of the increasing cost of hired labor to operate the existing farms. Because wages for hired labor are increasing rapidly while labor efficiency in farm operations is not improving significantly, we cannot delay the introduction of farm machinery until the size of farm is enlarged. Hence, we face a costly but unavoidable transformation. Who should pay the cost of mechanization will become an important subject in policy formulation.

For certain kinds of field work, machines can be designed for economical use by a single farm. In many cases, however, the economically feasible minimum capacity of a machine will be too large for the work volume of a single farm. Therefore, in order to minimize the cost of farm mechanization, efforts must be made both on the manufacturing side and by the users of the machines.

For illustration, if from the manufacturing viewpoint the minimum economically feasible size of a motor tiller is 8 horsepower, the users of the tillers will have to find sufficient work volume to utilize this capacity fully.

Because of small farm size, land fragmentation, biological characteristics of rice plants, etc., in Asian agriculture, use of machinery by individual rice farmers has often been considered economically infeasible. In this respect, manufacturers in Japan have contributed greatly by inventing machines suitable for the local conditions.

In order to spread the fixed cost of machinery which even at minimum capacity is too large for the work volume on a single farm, group ownership or cooperative use is often recommended. However, group ownership is not so popular as individual ownership. In spite of warnings about over-investment in farm machinery, individual ownership is likely to increase, with the owner of the machinery endeavoring to spread the fixed cost within his farm and outside of the farm.

Taking motor tillers as an example, most are owned by individuals who try to maximize the work volume of the machine. Tillers are used for many purposes, and a substantial part of the owner's receipts often comes from performing machine services for other farms. Tilling is often less important than use of the machine for transportation, threshing, and water pumping.

The buyers of motor tillers are not all large-size farmers. A young farm operator on a small farm often purchases a motor tiller to earn off-farm income by hiring out his own labor and machine services to other farms.

In the early stage of introducing motor tillers in Korea, some non-farm families in city areas used the tillers to earn income by transporting various things.

Thus, capability of multipurpose use is an important factor to be considered in designing machinery to increase the economic feasibility of farm mechanization on farms of the existing size.

Generally speaking, the rates of introduction of motor tillers in Korea are comparatively high in the following two agricultural areas: (1) The western plains area, where rice farming predominates, the area cultivated per farm is relatively large, and the cost of feeding draft cattle is high because field grasses are scarce. (2) Locations near urban-industrial centres, where diversified commercial farming is developing and off-farm employment opportunities are growing rapidly.

This implies that as farm resources are allocated increasingly to non-grain farming, such as vegetables, fruits, or livestock, and as the number of part-time farmers increases due to the fast growth of the urban-industrial sector, the area cultivated per farm will become a less important restricting variable for introducing motor tillers than it was in the stage of semi-subsistence food-grain farming.

The restrictive effect of size of farm differs for different kinds of machinery. In this respect, the experience of farm mechanization in Japan will be a valuable reference for other Asian countries.

In Korea there has been very little use of four-wheel tractors on general crop farms. Tractors are increasingly used for the development of hill land and on large-size livestock farms. In plains areas where rice is the main crop and paddy rearrangement is well done, four-wheel tractors can be used effectively for plowing. Even so, who should own these expensive machines is an unsolved problem. Tractors are regarded as less suitable than motor tillers for multi-purpose use on small-size family farms.

Korea has had no experience yet with the use of combines for harvesting rice. An economically feasible minimum capacity combine is still too large for the work volume of a single farm. Therefore, group control of the successive rice cultivation processes must be developed for effective use of this expensive machine. In order to be able to harvest a large area at one time, group decisions will be needed in the selection of seeds and in making time schedules for seedbed preparation, transplanting, fertilization, water control, etc.

To make uniform cultivation practices feasible, a high degree of homogeneity in the land base, soil fertility, irrigation conditions, etc., is also prerequisite. Land and water resource development, using heavy equipment, helps widen the area of homogeneity of the production base in a locality. This illustrates how evolution from simple types of farm machinery to complicated and expensive types requires increasing farmer adjustments in cultivation practices to meet the requirements of the machines.

Few studies have been made on the relation between land tenure and use of farm machinery in Korea. About two thirds of the general crop farmers are owner operators. Tenancy has been prohibited, except in special cases, under the Land Reformation Law (1950), and tenant farmers are a small portion of the total farms.

Near the urban-industrial centres, private urban capital is being invested in speculative land-holding or in commercial farming and such lands are generally managed by hired families. Use of farm machinery on such farms depends upon the objectives of the land holders. When the objective is to establish a commercial farm, rather than for merely speculative holding, the investment in farm machinery is high.

In areas located far from urban-industrial centres, the prices of land reflect the farm income from the land, for the demand for land for urban-industrial uses is increasing slowly. In such areas the incentive to hold land for rental revenue has diminished significantly in the 1960s, for the opportunity cost of the capital for holding the land is too high at existing interest rates. Also, the number of rural families who are willing to remain on farms as tenants has diminished.

Since in the Korean economy the opportunities for capital investment and labor employment are growing more rapidly in the urban-industrial sector than in agriculture, it is not likely that the old tenant farming that prevailed in the pre-1945 period would re-emerge even if the legal prohibition of tenancy were removed. Under the existing land tenure system in Korea the landlord-tenant relation does not seem to be an important factor in farm mechanization.

Land fragmentation

A typical farmer in Korea operates a little less than one hectare of crop land, consisting of both paddy land and upland. A farmer's crop land is seldom consolidated in a single parcel but is scattered in several parcels.

For efficient farm operation, consolidation of scattered fields was advocated even before the introduction of farm machinery. However, progress was slow until the mid-1960s.

Farmer participation in land rearrangement projects has increased remarkedly in the last several years. The increasing cost of hired labor has been a factor inducing farmer participation in rearrangement programs, as has the increased public financial investment in the programs.

Up to now, land rearrangment projects have been undertaken chiefly on paddy land, and the rearranged areas now cover one third of the total area of paddy land suitable for rearrangement. It is expected that around 70 percent of the suitable area will have been rearranged by 1975.

Land rearrangement provides a land base upon which some of the technical constraints upon farm mechanization are reduced.

In plains areas, where topography is flat and the top soils of the paddy lands are relatively homogenous, the consolidation of scattered fields into one parcel for each cultivator is being carried out with little disagreement among cultivators.

In rolling areas, however, the original variations in topographic conditions and soil fertilities among individual fields still remain after the rearrangement work is done. In such areas land rearrangement projects are carried out without accompanying consolidation programs, because of disagreements among cultivators. Differences in soil fertility within the rearranged areas are expected to be reduced as cultivation continues for a number of years, and mutual exchanges of fields for consolidation will be undertaken by voluntary agreements among the cultivators.

The impact of recent land rearrangement projects on the introduction of new technology shows up especially in the following activities:

(1) Improvement of the land base through paddy rearrangement has speeded up the adoption of yield-increasing technology. In particular, joint cultivation of rice has increased in the rearranged areas. A team of ten to twenty farmers makes group decisions on seed selection, seedbed work, transplanting, fertilization, disease and insect control, etc. Paddy land rearrangement and joint cultivation of rice facilitate the use of improved farm machinery. For example, group control of diseases and insects leads to the use of power sprayers. A motor tiller owned by one member of the team is utilized for other members. As a group, the joint cultivators can hire the service of expensive machinery

such as four-wheel tractors, power sprayers, and power threshers.

(2) Paddy land rearrangement has provided opportunities for improving farm roads from villages to individual field plots and has stimulated farmers' interest in local road improvements, thus reducing another factor restricting farm mechanization.

(3) Drainage and irrigation conditions are also improved by the program. Improvements in drainage, especially, have facilitated the introduction of double-cropping systems for off-season use of rice land. The increasing off-season production of quality vegetables under vinyl on well-drained paddy lands is providing additional cash income to rice farmers, and this contributes to the purchase of new farm machinery.

Since the social and private cost of land rearrangement increases rapidly as the suitability of the land for rearrangement decreases, we can not justify land rearrangement merely for farm mechanization. Some observers argue that for the introduction of motor tillers, improvement of farm roads is necessary. But tillers can be used effectively without accompanying rearrangement which requires a large amount of investment. In this regard, the experiences of other countries will provide valuable references for the Korean program.

Biological characteristics of rice cultivation

Because the major portion of the agricultural resources in Korea is employed in rice production, the biological characteristics of rice cultivation are an important factor affecting the type and degree of farm mechanization.

Field work for rice production on paddy lands, such as tilling, transplanting, weeding, fertilizer application, harvesting, etc., differs technically from similar operations on dry land for production of wheat, barley, corn, soybeans, etc.

The plowing and harrowing of paddy land in preparation for rice transplanting are done in flooded, muddy soil in the wet season, while the plowing of upland for sowing barley is done on dry-surface soil in the dry season. Hence, the tillage machinery for rice cultivation must be suited to muddy soil conditions.

Direct sowing of rice can not yet be recommended in the Korean climate. Problems of weed control and comparatively low yield are regarded as the major factors restricting direct sowing of rice on paddy land.

Yields of rice are affected substantially by the art of transplanting, such as spacing and number of seedlings per hill. Hence the machinery for rice planting must suit the biological characteristics of rice seedlings.

The kinds of weeds differ between paddy and upland, and the weeding of paddy land has to be done in muddy soil and under flooded conditions.

Thus, when we trace the series of field operations for rice cultivation on paddy land we realize that the technological possibilities of mechanization vary with the kind of field work, with corresponding variation in the relative cost of mechanization.

Among the various kinds of work processes for rice production, machinery has been adopted extensively for water pumping, threshing, and rice milling since the early stage of economic development in Korea. Use of power pumps is less affected by the biological characteristics of rice than is the use of cultivation machinery. The gap between the technological possibility and economic feasibility of mechanization seems smaller for water pumping, threshing, and rice milling than for cultivation processes.

Actually, the use of machinery for water pumping, threshing, and milling has not been regarded as "mechanized farming". Farm mechanization is loosely understood as a state of farming in which power machinery is used in rice cultivation processes. This notion may have arisen because the major portion of the labor input for rice production is for cultivation processes, and nobody likes to do manual labor on paddy land during the hot summer.

Urban-industrial growth is a basic factor in reducing the gap between technological possibility and economic feasibility of mechanization in plant cultivation processes.

Industrial development brings internal effects through supplying better quality farm machinery at relatively low prices. At the same time, urban-industrial growth raises wages for hired labor in the farm sector because of the outflow of labor. Also, urban-industrial growth makes possible higher farm product prices and farm incomes, which increase the economic feasibility of using machinery in cultivation processes.

Price and quality of farm machinery

During the 1960s the supply conditions of biochemical inputs for agricultural production were improved significantly in Korea. The construction of fertilizer plants made it possible to meet the domestic demand, and the supply prices of chemical fertilizers declined in recent years in real terms (see Table 4). Agricultural research and extension programs improved significantly in the last decade.

Compared to the biochemical inputs, the supply prices of farm machinery have not improved significantly. Imported machines from Japan and other industrialized countries are better in quality but higher in price than the domestic products due to scarcity and to taxes on the imported machines. To promote import substitution, the domestic manufacturers of farm machinery have been subsidized by the government for the last few years. Yet the supply prices are high and quality improvement is rather slow.

Basically, the low level of technology in the machinery industry has been the major cause of the expensiveness of domestic-made machines. Some domestic manufacturers justify the production of low-quality goods on the basis of limited purchasing power of farmers, the production of high-quality machines which are too expensive relative to the income level of farmers is discouraged.

In the past, government subsidies for farm machinery production have been provided to a large number of inefficient manufacturers. The subsidy programs are now being revised to help selected manufacturers improve the quality of farm machinery.

The government program for developing the farm machinery industry in the next few years will put emphasis on the manufacture of motor tillers, power sprayers, power threshers, and water pumping machines. Among these, special emphasis is to be put on motor tillers which are adapted to multi-purpose uses. The demand for sprayers, threshers, and water pumps which are attached to motor tillers is expected to increase rapidly.

Prior to expanding the manufacturing of motor tillers, in-

Table 4. Nominal Price Indices of Major Farm Inputs, Wholesale Prices, 1965–70.

Year	Farm wages	Power thresher	Power tiller (6-HP)	5-HP engine (kerosene)	Machinery parts	Fertilizer	Pesticides	All commodities
1965	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1966	116.9	108.3	104.5	109.1	115.7	100.0	103.6	108.8
1967	142.7	107.3	112.7	119.9	127.8	87.2	99.7	115.8
1968	178.3	140.4	117.6	135.6	139.8	87.2	113.7	125.2
1969	216.4	149.1	133.4	145.2	143.4	93.5	114.9	133.7
1970	285.5	175.0	—	149.4	164.7	96.6	113.2	151.4

Source: *Agricultural Cooperative Monthly Survey*.

Table 5. Farmers' Preferences on Horsepower of Motor Tillers

Horsepower	Number of farmers*	Percent
5	970	12.6
8	4,052	52.5
10	2,230	28.9
over 10	465	6.0
Total	7,717	100.0

* Around 8,000 farmers who had motor tillers were asked what horsepower they preferred in light of their experience.

formation is needed on the preferences of farmers regarding power and type of engine, kinds of equipment to be attached to tillers, etc. Recently, the Agricultural Extension Office made a survey of the opinions of about 8,000 farmers who have motor tillers. This survey has provided information useful for understanding the farmers' views:

(1) As for horsepower, the majority of farmers favor 8 to 10 horsepower, with a modal value of 8 HP (see Table 5). Generally speaking, small tillers are favored in the areas where light soils are prevalent, while 10 HP tillers are favored for tilling heavy soils. In the western plains area, where monoculture of rice is the dominant type of farming, top soils are comparatively heavy and large-size tillers are in demand.

Farmers making much use of motor tillers for transportation tend to require a high-horsepower machine. On the other hand, there is complaint that high-horsepower tillers are too heavy to be handled in the field by women and older workers.

Since, sprayers, threshers, pumping machines, etc., are often attached to motor tillers, the decision regarding optimum horsepower should take account of the power requirements of such equipment. In this respect, experience in other countries will provide valuable information for Korean agriculture.

(2) With respect to fuel, two types of engines are produced

Table 6. Types of Engines for Motor Tillers Owned by Crop Farmers in 1970

Types of engine	Number of farmers	Percent
Kerosene	4,978	64.5
Water cooled	3,982	
Air cooled	996	
Diesel	2,739	35.5
Water cooled	1,638	
Air cooled	1,101	
Total	7,717	100.0

Table 7. Major Obstacles Encountered in Use of Motor Tillers by Crop Farmers, 1970.

Difficulties	Total responses	Percent
(1) Prices of machine parts too expensive	2,048	21.2
(2) Lands not rearranged	1,802	18.6
(3) Repair stations too far away	1,519	15.7
(4) Poor conditions of roads	1,487	15.4
(5) Lack of skill in machine operation	1,175	12.2
(6) Frequent trouble with machine	609	6.3
(7) Horsepower too low	502	5.2
(8) Short supply of machine attachments	492	5.1
(9) Other	32	0.3

Table 8. What Farmers Do When Motor Tillers Need Repair

Repair activities	Number of observations	Percent
(1) Bring machine to repair shop	2,138	64.4
(2) Operator makes repairs himself	587	17.7
(3) Ask selling agents	276	8.3
(4) Invite technicians	272	8.2
(5) Wait for circulating technicians	48	1.4

Table 9. Preferences Regarding Types of Power Sprayers

Type of sprayer	Number of observations	Percent
Attachment to motor tiller	4,467	57.9
Mist-blower type	1,816	23.5
Hand-cart type	1,048	13.6
Basic type	386	5.0

for motor tillers: those using kerosene and diesel engines. Farmers think that kerosene engines are easier to start than diesel engines, but fuel costs more for kerosene engines. About 65 percent of the farmers having motor tillers use the kerosene-engine type. Water-cooled engines are far more common than air-cooled (see Table 6). As farmers become more skillful in handling machines and as the quality of diesel engines improves, the difference in fuel cost will become a more important factor in the choice of engines.

(3) Most of the farmers having motor tillers paid about one half of the price in cash, the remainder being covered by intermediate-term credit and government subsidy. The number of farmers who want to purchase tillers under the government assistance program exceeds the program funds available for tiller supply.

The farmers having motor tillers were asked what problems they encountered in effective use of the tillers. Their main responses, in order of frequency, were: machine parts are too expensive, crop lands are not rearranged, repair stations are too far away, local roads are in poor condition, machine operators lack skill (see Table 7).

At present only around 5 farmers in 1,000 have motor tillers, and the market system and repair services in local areas are far from adequate, which is a cause of the high cost of farm mechanization. In order to repair motor tillers, farmers must usually take them to a distant town or city. In some local towns farmers can not obtain repair service and machine parts.

The sample farmers were asked what they did about repairs. About 65 percent took the machines to places where repair shops were available, and 18 percent made their own repairs (see Table 8). Hence, local availability of repair service is an important factor for reducing the cost of farm mechanization.

(4) The advantages of motor tillers for multipurpose uses are creating demands for attached equipment. Especially, the substitution of machinery for human power in spraying, threshing, and water pumping is speeding up use of equipment attached to motor tillers. For example, when asked about their preferences for sprayers, about 60 percent of the farmers having motor tillers favored sprayers attached to motor tillers (see Table 9).

This partial information on farmers' views suggests a number of things needed for an effective policy to promote wider adoption of motor tillers.

(1) Quality improvements and lower prices for tillers and attached equipment are urgently needed.

(2) Improvements of the land base, such as land rearrangement and road improvement, are essential for an elastic adjustment of farming to labor shortage.

(3) Local availability of machinery repair service is critically needed to reduce the cost of mechanization.

(4) Training programs are needed to improve farmers' skills in use of machinery.

Farmers' limited purchasing power

Prices of motor tillers vary by type, size, producing firm, etc.

Table 10. Average Domestic Supply Prices of Major Farm Machines, in Won, 1971.

Kind	Description	Price
Motor tiller	Includes plow, rotary, and trailer	380,000
Sprayer	Attached to motor tiller	50,000
Thresher	Attached to motor tiller	90,000
Pumping machine	Motor	80,000

Including plow, rotary, and trailer, a motor tiller costs around 380,000 won (a little over US$1,000) (see Table 10). This is equivalent to 4.3 tons of rice at the domestic price in 1971 (around 88,000 won or $238 a ton).

The national average rice yield per hectare is a little over 3 tons. Hence to purchase a motor tiller by selling rice at the market will require the equivalent of the product from 1.43 hectares of paddy land.

The average size of farm is 0.9 hectares of paddy and upland. On the average, a farmer has around 0.6 hectare of paddy land producing 1.8 tons of rice. The price of a motor tiller is equivalent to 4.3 tons of rice. Hence, the money value of rice produced by an average size farm in a year is only about 40 percent of the price of a motor tiller. This indicates the low purchasing power of rice farmers for motor tillers.

If the farmer wants to attach a sprayer, a thresher, and a pumping machine to the tiller, it will cost him an additional 220,000 won ($595), which is equivalent to 2.5 tons of rice at the domestic market price. Very few rice farmers can afford to buy these attachments from their net income from rice farming.

Rice production is the major enterprise for general crop farmers in Korea. As previously discussed, the average cultivated area per farm is unlikely to increase significantly, in spite of the rapid urban-industrialization. The market surplus of rice from the limited cultivated area is small, and the receipts from rice per farm in a year depend upon yield and market price of rice. Since yield increase is rather slow, the annual receipts from rice are closely related to the price of rice.

Thus, the shortage of hired labor and high wage rates require the introduction of new machinery that is too expensive to buy from the farmers' rice receipts.

Rice farmers are insisting that the government raise the price of rice, but this is an important item affecting urban and industrial wage rates. The domestic real price of rice has increased significantly in recent years, and the present rate of increase is likely to continue in the next few years.

Even so, the net income from rice production alone will hardly enable farmers to purchase the new machinery they need so critically. Hence the importance of cash income opportunities other than rice production for inducing farm mechanization in the Korean agricultural setting.

Cash income earned from vegetable, fruit, and livestock production can make as important a contribution as can cash income earned from off-farm work in strengthening the purchasing power of farmers for machinery in the 1970s. Thus the availability of cash income opportunities in any locality is a strong factor affecting the degree of farm mechanization there.

Government Mechanization Programs

At the present stage of economic development in Korea, relatively few farmers have opportunities for cash income earnings other than from rice production, and even those privileged farmers seldom have enough cash savings to afford the purchase of expensive machinery. Hence, providing loans to farmers who want to purchase motor tillers and other machinery is an important part of the government's program for farm mechanization.

For those farmers who purchase a motor tiller with plow, rotary, and trailer, 70 percent of the purchase price will be provided by a 5-year intermediate term loan with an annual interest rate of 9 percent. For those farmers who purchase sprayers, threshers, pumping machines, etc., 50 percent of the purchase price will be provided by a 3-year loan at 9 percent.

Another important public program for farm mechanization is to assist manufacturers to increase productivity. The main idea of this program is to encourage specialized production of certain parts of a motor tiller by selected manufacturing plants. For example, two makers, the Dae Dong Industrial Co. and the Chinil Machinery Co., will be asked to produce motor cylinder liners, carburetors will be produced by the Seoul Steel Co. and one more plant, etc.

Assembly of machines will likewise be restricted to a few selected plants. For example, the assembly of water-cooled diesel engines for 8 and 10 HP tillers will be done by two authorized manufacturing companies.

The objective of this selective assistance program is to bring about quality improvement in farm machinery by inducing competition among a few manufacturers.

Another part of the government's policy for farm mechanization is teaching machinery skills and know-how through agricultural education and extension programs. Up to now, biological science and technology has received main emphasis in these programs, and farm level training in mechanical technology has lagged far behind. Some young farmers have learned the skills of machinery operation while they served in the army.

Training of the trainers and methods and facilities for teaching farmers about farm machinery are comparatively new subjects, on which much can be learned from other countries.

Conclusions: Some Research Needs

Few persons would have expected a labor shortage in agricultural production to come so soon in the urban-industrialization process of the Korean economy. Because of the dominance of small farms, land fragmentation, high degree of seasonal underemployment of farm labor, etc., the technological possibility and economic feasibility of farm mechanization were thought to be low. However, the rapid increase in wages for hired farm labor due to the outflow of rural youngsters has become a very strong inducement for labor-saving technology even with the existing small size of farms.

There is a wide gap between the need for farm mechanization and the actual use of machinery in agricultural production. In some farming areas, machinery is more urgently needed for public land and water resource development than for private management of individual farms. On most crop farms, however, the substitution of motor power for human and animal power is needed. Motor tillers capable of multipurpose use will be demanded extensively in the 1970s.

In the initial stages of farm mechanization, empirical research on ways to minimize the cost of mechanization is needed not only for the benefit of individual farmers but also by government agencies and manufacturing plants. The following research areas would seem to be of private and public interest:

(1) Estimation of the demand for heavy equipment for rural infrastructure developments, and evaluation of efficiency in the

use of heavy equipment by public agencies for development projects. (How many bulldozers will be needed for land rearrangement and farm road development? How can they be used most effectively?)

(2) Empirical study of the impact of rural electrification on farm mechanization. (How will availability of electric power in a farm village contribute to increasing the use of machinery?)

(3) Empirical study of the effects of farm road improvement on farm mechanization.

(4) Factors affecting the choice of motor tillers by farmers in terms of horsepower, kind of engine, attached equipment, etc.

(5) Farm management study of the effects of motor tiller use on farm enterprise combinations, farm expenses, farm receipts, household expenditures, etc.

(6) Relationship between farmer education, age, personal experience, etc., and adoption of mechanical technology.

(7) Empirical study of the effects of cash income opportunities other than from rice production on the introduction of farm machinery.

(8) Empirical study of the effects of local availability of machinery dealers and repair service on the introduction of farm machinery.

(9) Study on the adequacy of credit programs for promoting farm mechanization.

(10) Comparative cost analysis of machinery production in selected manufacturing plants.

MECHANIZATION AND RELATIONS BETWEEN FARM, NON-FARM, AND GOVERNMENT SECTORS

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The amount of fixed capital formation in Japanese agriculture in 1969 was Y1,172 billion, an increase of 250 percent in nominal terms or 120 percent in real terms since 1960. Comparisons are shown in Table 1, which gives also a rough classification of the fixed capital as land, buildings, farm machinery, plants, and livestock. The capital in farm machinery has increased remarkably. This form of capital increased by 16.9 percent in nominal terms or 15.5 percent in real terms in 1969 compared to the preceding year, exceeding the average annual increase of 13.7 percent in nominal terms or 13.1 percent in real terms from 1965 to 1968.

The changes in major farm equipment since the Second World War (Table 2) show a remarkable increase in power tillers, sprayers and dusters. In 1968, 56.6 percent of all farm households had power tillers, and in 1967, 79.6 percent of the paddy fields and 28.5 percent of the upland fields used power tillers, which is regarded as their maximum usage in the area.

On the other hand, the demand for riding tractors and reapers has continued to increase. Also, within the last one or two years the introduction of the head-feed and ordinary type of combine machines has increased. (The head-feed combine is a combination of power thresher and reaper.)[1]

In this paper I would like to analyze the economics of farm mechanization, with special reference to the power tiller and large-size machines such as the riding tractor and combine.

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Table 1. Capital Formation in Japanese Agriculture.

(Unit: billion yen)

Item		1960	1965	1969	Average rate of increase during 1960–1968
Capital formation	A	333.7	689.5	1,172.2	15.5%
	B	438.5	689.5	961.4	9.3
Land	A	104.1	220.1	380.1	16.1
	B	146.2	220.1	306.0	9.2
Buildings	A	63.7	156.1	274.5	18.9
	B	100.2	156.1	190.6	8.2
Farm machinery	A	112.4	213.5	367.0	13.7
	B	113.3	213.5	351.2	13.1
Plants	A	17.0	49.5	63.6	17.0
	B	25.0	49.5	48.8	8.7
Livestock	A	36.5	50.3	87.1	10.7
	B	53.8	50.3	64.7	0.4

A: nominal terms B: real terms (1965 yen)

Source: Japanese Ministry of Agriculture and Forestry, *Nōgyō oyobi Nōka no Shakai Kanjyō* (Social Accounting of Farm and Farm Household), 1969.

Economics of Small-Scale Mechanization

The mechanization of small-scale Japanese farms is different from that of large-scale Western farm enterprise in the form of its application. The differences are detailed below:

1. Mechanization in Western countries has been applied to upland farming, but mechanization in Japan is primarily in watered paddy fields. A study in 1967 shows that the mechanization ratio in Japan was 85.8 percent in paddy fields and 39.9 percent in upland fields.[2]

2. Although mechanization has occurred evenly in all processes of cultivation in Western countries, such a balanced advance is not observed in Japan. In the latter case, machines were not introduced in all processes of paddy cultivation. They were only used instead of human labor in plowing and harrowing and levelling the ground. In Japan, mechanization is taking place gradually in transplanting, reaping, etc.

3. In Western countries, yields have increased through mechanized deep-tilling. In Japan, however, it is not clear what effect the use of tillers has had on the yield of rice per acre. Yoshio Itoh points out that the deep tilling capacity of the power tiller is no greater than that with cattle power.[3] Results obtained by the National Agricultural Experimental Stations in various

Table 2. Changes in the Major Equipment on Farms, Japan, 1955–69.

(Unit: 1,000)

Year	Power tiller	Riding tractor	Rice trans-planter	Sprayer	Duster	Grain reaper	Combine	
							Head-feed type	Ordinary type
1955	87	0.1		76	11			
1958	227	0.2		130	25			
1960	746	5		232	73			
1962	1,414	11		342	94			
1964	2,184	13		524	180			0.1
1965	2,490	19		600	250	18		0.1
1966	2,725	39		717	409	36		0.2
1967	3,021	58	12	906	724	71	1	0.3
1968	3,030	124	37	1,041	893	162	16	0.5
1969		179	82			353	47	0.7
Rate of diffusion (percent)	56.6	3.4	1.5	19.5	16.8	6.6	0.9	

Source: Akira Takei, *Nihon Nōgyō no Kikaika* (Mechanization in Japanese Agriculture), 1970.

Table 3. Changes in Rice Yield by the Use of Power Tillers

(Unit: kg/10 ares)

Location of Agricultural Experimental Station	Change of Yield
Akira	+2
Nara	+5
Hiroshima	−8
Ehime	+11
Kōchi	+0.6
Yamaguchi	−37

Source: Agricultural Improvement Bureau, Ministry of Agriculture and Forestry, *Doryoku Kounki ni kansuru Shiken Kenkyu* (Studies on the Experimental Use of Power Tillers), 1960.

prefectures have varied; some show an increase in yields while others record a decrease (Table 3).

4. In Japan, machines have been substituted for human labor, but mechanical power is not yet used in all plowing instead of cattle and horses. Table 4 compares power provided by cattle and horses with that provided by power machinery. (Cattle are converted at 0.5 horsepower per head, horses at 0.6 horsepower.) These estimates are also traced graphically in Fig. 1.

Fig. 1. Historical Changes in Agricultural Labor Population and Power Used in Agriculture.

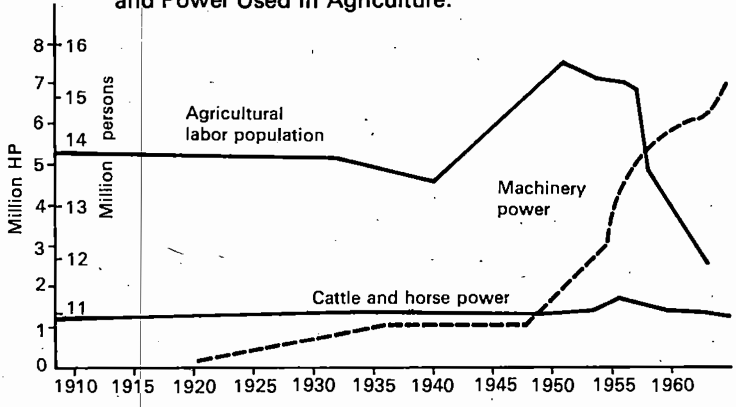

Table 4. Historical Record of Application of Power in Japanese Agriculture.

Year	Cattle and horses		Machine power (1,000 HP)
	Number (1,000 head)	Amount of HP (1,000 HP)	
1907	2,163	1,277	1
1912	1,334	1,334	5
1920	2,266	1,320	37
1935	2,416	1,403	1,109
1947	2,503	1,400	1,129
1953	3,058	1,682	3,150
1955	3,575	1,880	4,606
1957	3,408	1,786	5,596
1959	3,093	1,624	6,341
1960	3,013	1,574	6,331
1961	2,931	1,527	6,491
1962	2,878	1,494	
1963	2,808	1,451	6,634
1964	2,603	1,341	7,484
1965	2,207	1,136	8,109
1966	1,185	949	

Source: Information for horsepower from cattle and horses is from the Planning Division, Minister's Secretariat, and the Agriculture Policy Bureau, Ministry of Agriculture and Forestry, *Nihon Nōgyō no Kikaika* (Mechanization of Japanese Agriculture), 1963. As to machine power, the author computed the horsepower of electric and petroleum motors.

Total power of cattle and horses changed very little for many years, but it began to decrease after 1955. Machine power has shown a sharp and sustained rise since 1947, and the agricultural labor population has continuously declined since 1950. In other words, Fig. 1 confirms the fact that the increase in agricultural machinery is inversely proportional to the decrease of human labor in agriculture.

Power tillers dominate farm mechanization in Japan. This differs from Western countries, and various kinds of research are being done on this subject at the present time.

Nobufumi Kayō (1962)[4] has concisely classified explanations of the adoption of power tillers into five categories, and adds his own critical opinion. The five categories are as follows:

1. Income Effect Theory: The returns from use of power tillers fall short of their cost and, in fact, investment results in over-investment. Nevertheless, power tillers continue to be brought into use because the farmer's income has increased. Furthermore, the inducement for this investment is not the same as that commonly assumed in farm management analysis because household economy and business enterprises are not clearly distinguished in Japanese agriculture. In other words, this theory regards the motive to purchase power tillers as something similar to the desire for durable consumer goods, such as washing machines, rather than pure producer goods.

2. Demonstration Effect Theory: This theory holds that farmers buy a power tiller to compete with next-door farmers who are already using one. This would be called "keeping up with the Joneses". Such a phenomenon is widely known as the demonstration effect, a principle advocated by J.S. Duesenberry to explain the main motives for the purchase of consumer goods. The application of such a theory to the introduction of power tillers is based on the assumption that they are not producer but consumer goods.

3. Disintegration of Patriarchal Family Theory: As sons and daughters of farmers have shown a strong tendency to abandon farms in recent years, the heads of farm families buy tillers to encourage their children to remain in the traditional profession of agriculture. According to this theory, this situation is due to the weakening of the patriarchal family system.

4. Increased Leisure Valuation Theory: Mechanization is not used to provide additional time for more intensive farm management or for a side-business to increase earnings, but to increase leisure time.

5. Farmers' Physical Mutation Theory: In the days before the Second World War, farm training was started at the age of about twelve, when a young boy finished primary school. After

the War, this type of hard traditional training was no longer enforced because of the collapse in the patriarchal family system, and the period of compulsory education was extended up to the age of 15. Thus more and more children of farmers began to go to high school. This resulted in building a non-robust body type that could not stand heavy farm work. This theory holds that for these reasons tillers have gradually been employed in farm work.

All the above mentioned theories try to explain the mechanization of small-scale farms from viewpoints other than that of economic rationality. However, the average purchasing price of a tiller is about ¥190,000 (US$528) without attachments. If attachments are included, the price may be ¥300,000 (US$833). With the annual average farm household income at ¥670,000 (US$1,861) in 1964, it is easy to realize how expensive it is to buy such machinery. Such being the case, before a farmer decides to buy a power tiller he is naturally obliged to bear in mind the foreseeable payments.

In fact, the result of a survey carried out on 2,061 farms by Kikaika Shinkō Kyōkai (The Association for Promotion of Machinery) showed that 84 percent of all the farmers surveyed adopted the use of power tillers to substitute for human labor, and very few did it for demonstration or for other non-economic reasons. It seems, therefore, necessary to review the motives for the use of power tillers by Japanese farmers from the standpoint of economic reasons, as distinct from the opinions mentioned above.

Why Small-Scale Mechanization Has Spread

First of all, let us see how power tillers have spread throughout Japan. As shown in Table 5 there is a big difference among regions in the relative numbers of power tillers.

In the high rice producing regions such as Tohoku (North-Eastern) and Hokuriku (North-Western) the number of tillers is 61.3 per 100 families, but in the remote areas like Kyushu it is only 31.4.

Such regional differences are attributed to various factors, among which land improvement projects are very important. Once a land improvement project is carried out the drainage

Table 5. Number of Power Tillers in Use per 100 Farms.

Kind of District	Number of Tillers 1960	Number of Tillers 1967
National average	8.6	56.0
Industrial districts		
Districts surrounding big industries	9.6	53.0
Suburb districts of local industries	6.6	61.3
Agricultural districts		
Districts with high rice production	12.1	61.3
Districts producing commercial agricultural products	9.1	56.4
Districts of general rice farming	7.5	58.3
Districts producing crops other than rice	6.6	31.4
Remote districts	2.1	31.4

Source: Ministry of Agriculture and Forestry, *Chiiki Nōgyō no Bunseki* (Analysis of Regional Agriculture), 1969.

Table 6. Investment in Land Improvement.

(Unit: million yen)

Year	Total Investment (A)	Public Investment (B)	Ratio of Public Investment (B/A)
			percent
1910	11,979	979	8.3
1920	15,982	1,267	7.9
1930	23,849	6,534	27.4
1940	19,438	7,185	37.0
1950	33,626	22,550	67.1
1960	76,407	52,901	69.2
1964	98,262	70,518	71.8

Source: The National Research Institute of Agriculture, Ministry of Agriculture and Forestry, *Nihon Nogyo no Choki Tōkeishū* (Long-Range Statistics for Japanese Agriculture), Vol. 1, 1967.

is better, rearrangement of the paddy fields makes each plot larger, and the introduction of machinery is easier.[5]

In pre-War Japan, land improvement projects were generally carried out by private landowners, with very little investment by the Central or Prefectural Governments. After the Second World War, as shown in Table 6, the proportion of public investment in the total investment gradually increased. This was due to the land reform, which reduced the landowners' return for their capital investment. Thus the share of government investment reached 71.8 percent in 1964.

Such public investment has drastically increased the total value of investment in land improvement. For example, the investment in 1964 was about 8.2 times that in 1910. This is one of the main factors in the extension of farm mechanization.

Investment in land improvement (agricultural social investment), however, has not been even all over the country; differences are seen between regions. Table 7 shows the estimated social

Table 7. Amount of Social Capital Stock per Hectare of Cultivated Land.

(Unit: 1,000 yen, 1963 value)

Region	1918–1952	1963
Tōhuku	128	225
Kantō	98	147
Tōkai	132	369
Hokuriku	200	334
Kinki	97	178
Chūgoku	97	225
Shikoku	95	197
Kyushū	102	174

Source: Social capital stock for agriculture is calculated from data in *Norin Gyōgyō no Chiikibetsu Shihon Sutokku no Suikei Kekka* (Estimation of Regional Capital Stock for Agriculture and Forestry), by the Ministry of Agriculture and Forestry, January, 1966, and cultivated land area from data in *Nōrinshō Tokeihyō* (Statistical Tables of the Ministry of Agriculture and Forestry).

capital stock for each agricultural region. (The two newly developed industrial regions, Tokai, between Osaka and Tokyo, and Chugoku, near Osaka, are excluded.)

The social capital investment is relatively greater in such advanced rice-producing regions as Tohuku and Hokuriku and less in remote regions like Kyushu Island. This fact seems to lead us to the conclusion that the increase in social capital investment for land improvement accompanies the extended use of power tillers.

Next, let us consider the second factor for the extension of power tillers. As mentioned earlier, the agricultural labor population began to show a marked decrease after 1954. This reflects the fast growth of the Japanese economy. At the same time, some members of each farm family started to earn extra income by taking side jobs. In other words, there has been an increase in the number of so-called part-time farmers.

The proportions of part-time farmers have been calculated by Takeo Misawa (Table 8). If these estimates are accurate, part-time farmers remained close to 54.8 percent of the total up to 1950, but have increased drastically since about 1955 and finally reached 78.5 percent in 1965.

Furthermore, a detailed study of the income structure of these farmers reveals that for many the income from side-jobs surpasses regular income in agriculture, so that a majority are

Table 8. Ratio of the Part-time, First Class and Second Class Farmers.*

Year	1938	1950	1955	1960	1965
First class farmers	30.6	31.8	37.6	33.6	36.8
Second class farmers	24.2	23.0	27.5	32.1	41.7
All part-time farmers	54.8	54.8	65.1	65.7	78.5

Source: Takeo Misawa "An Analysis of Part-time Farming in the Post-war Period", *Agriculture and Economic Growth: Japan's Experience,* edited by Kazushi Ohkawa, Bruce F. Johnston and Hiromitsu Kaneda, 1969.

* See Note 6.

now the so-called second class part-time farmers[6]. This fact signifies the decrease in the agricultural labor population or labor force, which has been accordingly reflected in a sharp rise of agricultural labor costs.

In addition, the relatively lower down payments and the improved performance of agricultural machines and implements may be counted as a third factor in the extension of agricultural mechanization. Before the Second World War, agricultural machines were manufactured mostly in middle or small-sized factory enterprises, on the basis of past experience and needs. Since the War, however, production techniques have improved vastly.

This was, in a sense, one of the results of the switch-over from small scale plants to factories for the production of agricultural machines and implements. The latest mechanical engineering techniques are presently applied in planning, production, and materials, which are inspected by experts. Thus, improvement in quality and stabilization of prices of machinery have been attained.[7]

Now let us consider the ratio between the average part-time wage for male farm workers in agriculture and the prices of agricultural machines and implements. The annual part-time wage was equivalent to 28.3 percent of the prices of agricultural machines and implements in 1887, and this gradually rose to 153.7 percent in 1950 and reached 256.2 percent in 1963. The prices of agricultural machines and implements have increased relatively less than labor costs.

Fourthly, the rise in farmers' income level can be pointed out. This is due to two reasons, the popularization of side-jobs among farmers and the inflated price of rice. Table 9 shows the result of the investigation conducted by Kikai Shinkō Kyōkai (The Association for Promotion of Machinery) of 2,061 farm households in 1964. According to this Table, 77 percent of the cost of power tillers came from the farmers' own funds. Very little capital was secured from the Modernization Fund (a governmental low-interest fund) or other sources.

Such a high ratio of personal financing indicates a levelling-off of farmers' incomes and also reflected the limitations of financial organizations with regard to agricultural mechanization. In this

Table 9. Average Proportions of Funds for Purchasing Power Tillers Obtained from Specified Sources by Farmers Using Those Sources, by Size of Farm, 1964.

Farmer's land-holding (hectares)	Own funds	Moderniza-tion fund	Farming fund	Fund from cooperative	Other sources
	percent				
Less than 0.5	73	-	12	6	21
0.5–1.0	78	16	6	6	7
1.0–1.5	76	16	7	8	3
1.5–2.0	76	16	7	8	3
1.5–2.0	79	15	5	6	6
More than 2.0	79	17	5	7	5
Average	77	16	6	7	5

Source: Nōkigu Iinkai (Committee on Agricultural Machines and Implements), *Nōgyōyō Torankutā no Keizaiteki Kōka ni kansure Chōsa* (Studies on the Economic Effects of the Use of Agricultural Tractors), 1965. "Less than 0.3 hectare" and "0.3–0.5 hectare" are here totalled as "less than 0.5 hectare". The percentage shown for a source is the average of percentages among those farmers actually using the source. Therefore the total in each line is more than 100 percent.

situation, farmers are obliged to raise the necessary funds and to arrange repayment themselves; this forces them to take economic or practical types of action.[8]

Finally, the fifth and most important factor is the change in farmers' entrepreneurship. Prior to the Second World War, Japanese farmers possessed very little personal initiative. Seiichi Tōbata spoke of them in 1936 as "mere managers."[9] This pointed out the fact that in Japanese agriculture the role of entrepreneurship was long played by such bodies as the central government and local public and agricultural cooperative institutions, and the farmers themselves did not play a sufficient role. In the words of J.A. Schumpeter, who defined entrepreneurs as those who further the economy, the Japanese farmers in the pre-War period were not actively developing Japanese agriculture.

To sum up, the promotion of agricultural mechanization centering around the distribution of power tillers has made Japanese farmers familiar with practical economy. It has also forced them to cease being "mere managers". Thus, it may be concluded that the recent extensive use of power tillers has been advanced in order to secure a certain amount of rice at the lowest possible cost, rather than to increase the yield. It is a practical substitution of machinery for human labor. This is to say that the mechanization of Japanese agriculture is really logical.[10]

However, such small-scale mechanization does not contribute very much to increasing agricultural labor productivity. In order to increase labor productivity, large-scale mechanization is needed. In the following section we will consider some problems concerning large-scale mechanization.

Large-Scale Mechanization

According to Table 2, the number of reapers in 1969 was 353,000, a diffusion ratio of 6.6 percent. Corresponding figures for riding tractors were 179,000 (3.4 percent) and for rice transplanters, 82,000 (1.5 percent). Farm mechanization can be divided into two phases. The first phase, 1955 to 1966, is dominated by the use of the power tiller. The second phase, from 1967 to the present, is dominated by the use of the rice transplanter and the combine. Beginning in 1963 the number of combines of the ordinary type started to increase with the help of subsidies under the First Agricultural Structure Improvement Scheme; the number reached 736 in 1969. Because of the high cost of this machine (each about 6 to 7 million yen) diffusion is difficult without government subsidies and efficient utilization.[11]

As there are very few examples of large-scale mechanization in Japan, we have to analyze this through selective cases. We have taken as examples the Ariake Land Reclamation and Minami Kawazoe Land Reclamation in Saga Prefecture, the Shiranui Land Reclamation in Kumamoto Prefecture, and the Hachirō Gata Land Reclamation in Akita Prefecture. Let us first consider the records of the Ariake Land Reclamation Ex-

Table 10. Net Return in Rice Production According to Mechanization Pattern, Ariake Experiment.

Item	Unit	Large-scale mechanization direct sowing	Small-scale mechanization direct sowing	Large-scale mechanization transplanting	Traditional transplanting
Yield	kg/10 ares	595	628	573	591
Output	yen	83,029	87,464	79,867	82,349
Production cost*	yen	36,749	34,603	34,708	39,020
Cost of machinery	yen	6,369	4,117	3,787	3,955
Net return	yen	46,280	52,861	45,155	43,329
Income	yen	62,930	70,286	62,980	65,304
Family labor	hours	66.6	69.3	71.3	87.9
Labor return per hour	yen	944.9	1,014.2	883.3	742.9

Source: Technical Committee, Ministry of Agriculture and Forestry, and Agricultural Experimental Station in Saga Prefecture, *Sōgō Jikken Nōgyō Sōgō Hōkokusho* (General Report of General Experimental Farm), 1970.

* Production cost includes cost of machinery.

perimental Farm study carried out by the Technical Committee of the Ministry of Agriculture and Forestry and the Agricultural Experimental Station in Saga Prefecture. The Ariake Farm was established to study high utilization of paddy fields, increase of labor productivity, and management of large-scale dairy farming.

The experiment was carried out from 1964 on 45 hectares of paddy with 30 farm households. The farm was divided into two segments. One segment was 27 hectares with 90-are plots and the other 18 hectares with 60-are plots. The 90-are plots were again divided into two compartments. Even though these compartments were utilized profitably with large-scale machines, they could be utilized more profitably with small-scale machines.

Table 10 shows the results of this experiment. In rice production with the small-scale mechanized direct sowing pattern, the net return and income per 10 ares were Y52,861 and Y70,286, respectively. With the large-scale mechanized direct-sowing pattern the net return and income were Y46,280 and Y62,930. The net return and income with the small-scale mechanized direct-sowing pattern was thus higher than with the large-scale. This was due to greater efficiency and better yields. (Harvest loss in the large-scale mechanized pattern has been a special problem.)

Diffusion of large-scale machines is difficult due to the lower net return and lower income compared to small-scale machines. This is a general situation. A cooperative farm operated with big farm machines in the same Saga Prefecture provides another example.

Hiroshi Eriguchi analyzes this co-operative farm (149 members, 37.3 hectares of land, 2 tractors, 1 combine, 5 employees) as follows:[12]

In Table 11, he compares a rice production cost survey average farm to the co-operative farm. Net return per 10 ares on the average farm and the co-operative farm were Y41,145 and Y41,957, respectively, but farm incomes, including labor return, on the average farm and on the co-operative farm were Y59,765 and Y46,757, much higher on the average farm. This is because labor input on the co-operative farm was less than on the average farm and the labor return on the co-operative farm was smaller than on the average farm.

Table 11. Comparison of Rice Production Return between Average Farm and Co-operative Farm (per 10 ares).

Item	Average Farm	Co-operative Farm
Output	571 kg	507 kg
Gross return	79,633 yen	68,416 yen
Production cost	38,488	26,459
Net return	41,145	41,957
Income	59,765	46,757

Source: Dept. of Agr. Econ., Saga Univ. *Saga Heitanchi ni okeru Nōminsō Bunkai to Ogata Kikaika Kyōdō Keiei no Shūekisei* (Changing Status of Farmers and Returns to Large Scale Mechanized Co-operative Farm), 1970.

Table 12. Comparison of Labor Input in Rice Production between an Average Farm and a Co-operative Farm in Saga Plain, 1968.

Item	Average Farm	Co-operative Farm
Seed preparation	0.5	0.5
Seed bed preparation	4.4	4.4
Soil preparation	9.7	1.1
Basic fertilization	3.6	0.2
Direct sowing	0.4	—
Transplanting	23.8	20.0
Additional fertilization	3.0	0.8
Weeding	6.3	2.6
Water control	8.8	2.0
Prevention	5.8	0.4
Reaping and threshing	37.5	0.4
Drying and hulling	5.6	3.2
Total	109.4	35.6

Source: Dept. of Agr. Econ., Saga Univ., ibid., 1970.

Table 12 shows the results of the survey carried out by Eriguchi regarding labor input necessary for producing rice per 10 ares. This input on the average farm and the co-operative farm is 109.4 and 35.6 hours, respectively, 73.8 hours less on the co-operative farm.

The hours used for transplanting are almost same on the average farm as on the co-operative farm, but transplanting hours calculated for the co-operative farm constitute 56.2 percent of the total labor input for producing rice, so transplanting by human labor is the biggest problem in this large-scale mechanization pattern.

The reasons there was so much labor for transplanting on the co-operative farm were: (1) the availability of enough labor, since the co-operative farm was operated by 149 fishermen and they could do the transplanting themselves, and (2) the fundamental technological reasons—reduction in yield using direct sowing or transplanting by machine. Land improvement alone is not enough. The highest yield from the same kind of reclaimed land with direct sowing carried on by the agricultural experimental station in 1963 was 436 kg per 10 ares, while the average yield in transplanting by human labor was 561 kg. This difference shows why human labor is still needed for transplanting.

A similar example is provided by Hachirō Gata Land Reclamation in Akita Prefecture. In 1970, 460 families had been settled on 4,600 hectares of land, thus providing 10 hectares per family. Even on a large-scale farm like this, 98.8 percent of the land was transplanted by human labor. Direct sowing was used only on the remaining 1.2 percent. This reduction of the yield is also substantiated in the Minami Kawazoe Land Reclamation. At the Agricultural Experimental Station in Hachirō Gata the target yield of 450 kg per 10 ares has not been reached even in the year of the highest yield, 1967, when it was 378 kg. Compared to the yield of more than 500 kg with transplanting by human labor, there was a difference of 120 kg.

Therefore, transplanting by human labor was preferable and there was no shortage of labor for it because the transplanting in the suburbs of Hachirō Gata is over by the end of May and the same labor could be used in Hachirō Gata where transplanting continues until the 20th of June. However, even in this area the shortage of labor and increase in wage rates necessitate the introduction of direct sowing and transplanting by machine.[13]

Another example can be seen in Shiranui Land Reclamation in Kumamoto Prefecture, where large-scale mechanization is taking place with direct sowing. This Shiranui Land Reclamation (400 hectares) was begun by the Ministry of Agriculture in 1951. It has taken 19 years to complete and has cost ¥2.67 billion. In 1967, 90 farm households settled there, receiving 4 hectares each. (The remaining 40 hectares were given to farmers in the suburbs who needed to increase their farm land.) During 1967 and 1968 the Kumamoto Prefecture Government spent a total of ¥410 million in developing this farm in the Land Improve-

Table 13. Labor-Input Hours in Rice Production in Shiranui Land Reclamation.

Item	Direct sowing in water	Traditional pattern
Seed preparation	0.1	0.6
Soil preparation	2.4	10.5
Seed bed fertilization	3.5	30.7
Basic fertilization	1.0	4.0
Ordinary fertilization	0.7	2.2
Weeding	5.7	9.8
Prevention	2.0	6.3
Water control	3.0	8.6
Reaping and threshing	0.6	32.7
Drying and hulling	2.5	8.4
Rest	2.0	0.1
Total	23.5	113.9
Yield/10 acres	394 kg	543 kg

Source: Agr. Expt. Sta. in Kumamoto Prefecture, *Nōgyō Kikaika ni kansuru Shiken Hōkokusho* (Experimental Report in Agricultural Mechanization), 1971.

ment Scheme. Each farm has been divided into two plots (2 hectares each) and large-scale mechanization using 40 tractors, 8 combines, and a country elevator, has taken place.

According to Table 13, the yield per 10 ares with the direct-sowing pattern on reclamation land was 394 kg, but even this was not so high as with the traditional pattern.

This pattern was introduced, however, in order to save labor in the busy season like June and July.[14] By introduction of direct sowing, labor productivity increased remarkably, from the 4.8 kg of the traditional pattern to 16.8 kg.

With this direct-sowing pattern the operator's own labor can be reduced, employed labor becomes unnecessary, and women can be released from farm work, because the total labor input is only 23.5 hours in this pattern compared with 113.9 hours in the traditional pattern. At present, however, human labor is still used in this pattern and needs to be replaced by mechanization.

We have to note that this Shiranui Reclamation Land is one of the few examples where mechanization is taking place in almost all fields.

Problems of Large-Scale Mechanization

In the above four examples, five important problems were mentioned. The following ideas are given as to how to introduce large-scale mechanization.

1. In large-scale mechanization, land improvement (irrigation and drainage, etc.) is an essential foundation. Improved drainage hardens the earth, which aids efficient utilization of large machinery. Enlargement of plot size and farm roads are also needed for large machines to be used.

Table 14 shows the potential area for mechanization and existing paddy field rearrangement. Only 38.6 percent of the paddy land in Japan is suitable for mechanization, with a degree of slope less than 1/100 in units of more than 50 hectares. Looking at this regionally, 59.0 percent of the land in Hokuriku is suitable, 20.3 percent in Tōhoku, and 22.2 percent in Minami-kyūshū. Improved lands of area above 20 ares where mechanization is possible are only 4.6 percent of the nation's cultivated land. Regionally, the proportion of such land ranges from 10.7 percent in Hokuriku and 6.0 percent in Kitakantō to 1.4 percent in Tōsan and 0.8 percent in Shikoku.

To promote mechanization, land improvement schemes are very important and a large amount of money is needed. In the Shiranui Land Reclamation given here as an example, the amount of investment was ¥100,000 for each 10 ares. For large-scale mechanization, a large amount of money from national or local governments is needed as a pre-investment.

2. Improvements are needed in farm machinery such as rotary

Table 14. Potential Area for Mechanization and Existing Rearranged Paddy Land.

(Unit: 1,000 hectares)

Regions	Cultivated land (1970) (A)	Potential mechanization area (1968) (B)	Area of re-adjusted paddy of more than 20 Ares (C)	(B/A)	(C/A)
				percent	
All Japan	5,796	2,239	267	38.6	4.6
Hōkkaidō	987	238	40	24.1	4.1
Tōhuku	1,030	496	56	48.2	5.4
Hokuriku	441	260	47	59.0	10.7
Kitankantō	634	285	38	45.0	6.0
Minamikantō	236	89	14	37.7	5.9
Tōsan	217	44	3	20.3	1.4
Tōkai	430	192	21	44.7	4.9
Kinki	350	173	7	49.4	2.0
Sanin	119	36	4	30.3	3.4
Sanyō	300	90	10	30.0	3.3
Shikoku	243	82	2	33.7	0.8
Kitakyūshū	535	193	21	36.1	3.9
Minamikyūshū	275	61	5	22.2	1.8

Source: Ministry of Agricultural and Forestry, *Nōgyō Nenji Hōkokusho* (Agricultural Annual Report), 1971.

tooth harrows and grain drills as well as large-scale transplanting machines.

3. Weed growth is a greater problem in direct sowing, and weeding takes a lot of labor and money. Hence better methods are needed to prevent weed growth.

4. Utilization of large-scale machines is concentrated in the seeding season. Proper use of these machines should be reconsidered.

5. Closely related to the above points, the yield in large-scale mechanization is lower and less reliable than with traditional cultivation. Therefore, at present, the well-mechanized areas using large-scale machines are (1) areas where there is part-time farming, and (2) areas where rice is only a minor product and livestock such as dairy cattle, poultry, etc., are the major products. This is substantiated by the survey data of the Agricultural Experimental Station in Fukuoka Prefecture. According to this survey, the farmers who use large-scale machines are (1) part-time farmers with less than 150 ares of land, and (2) farmers whose major enterprise is not rice but poultry breeding, vegetable growing, etc.[15]

The above facts show that for the success of large-scale mechanization, either the seasonal labor in agriculture should be shifted to other industries or the major portion of the decrease in profit should be covered by the other sources of income.

Conclusions

After the Second World War investments in farm machines increased remarkably in Japanese agriculture. This occurred in two phases. In the first phase, from 1955 to 1966, the power tiller dominated farm mechanization, and in the second phase, since 1967, the rice planter and combine dominated farm mechanization.

In this paper we have analyzed the economics of small-scale mechanization dominated by power tillers and large-scale mechanization dominated by riding tractors and combines.

First of all, in recent years mechanization has been advanced in order to secure a certain amount of rice at the lowest possible cost, rather than to increase the yield. In other words, mechanization is a logical substitute for human labor. However, such mechanization does not contribute very much to increase farm labor productivity. To increase farm labor productivity, farm-scale increase and large-scale mechanization are essential.

For extensive use of large-scale mechanization in Japan, some problems must be solved. Without this there can be no progress.

The number of farmers leaving the land will continue to increase. This can be seen in the farmer's census carried out in 1965 by the Ministry of Agriculture and Forestry. Of the six million farm owners in the country about 10 percent have abandoned their farm land. Owners giving up their land held only 1.6 percent of the total land or only 1.1 percent if the ratio is converted into cultivated area.

Such being the case, it is very difficult to establish Japanese agriculture on a large-scale mechanization basis. It will take many years to reach full mechanization in Japan, with the use of major farm equipment such as riding tractors and combines and remarkably increased farm labor productivity.

[1] Takei, Akira, *Nihon Nōgyō no Kikaika* (Mechanization in Japanese Agriculture), 1971.

[2] Ministry of Agriculture and Forestry, *Chiiki Nōgyō no Bunseki* (Regional Agricultural Analysis), 1969.

[3] Itoh, Yoshio, *Inasaku Chūgata Gijutsu no Keisei* (Formation of Medium Size Rice Production Technique), 1966.

[4] Kayō, Nobufumi, *Nihon Nōgyō Kikaika no Kadai* (Problems in the Mechanization of Japanese Agriculture), 1962.

[5] The use of mechanization is largely due to land improvement projects, especially in the advanced rice producing areas. In this respect, refer to: "Land Improvement Schemes and Innovation in Agricultural Technology", by Keizō Tsuchiya, *Rural Economic Problems,* Vol. 1, 1964.

[6] "Part-time farmers" means those farmers who have family members earning extra income by taking side-jobs. First class part-time farmers are those whose family earnings from farming exceed those farm side-jobs. Second class are those for whom the contrary is true.

[7] Uno, Kōzo, and others, *Nihon Nōgyō Nenpō* (Annual Report on Japanese Agriculture) Vol. 8, 1958.

[8] Kudō, Zyurō, "Nōgyō Rōdō no Gōrika to Kikairyō no Keizaisei ni kansuru Kenkyū" (An Economic Study of Farm Machinery on the Japanese Family Farm), *Tōhoku Nōgyō Shikenjō Hōkoku* (Bull. of Tohoku Natl. Agri. Expt. Sta.) Oct. 1962.

[9] Tōbata, Seiichi, *Nihon Nōgyō no Tenkai Katei* (Evolutionary Processes of Japan's Agriculture), 1936.

[10] Tsuchiya, Keizō, "Mechanization in Small Scale Agriculture" *in Agriculture and Economic Growth: Japan's Experience*, edited by Kazushi Ihkawa, Bruce F. Johnston, and Hiromitsu Kaneda, 1969.

[11] Takei, Akira, *Nihon Nōgyō no Kikaika* (Mechanization in Japanese Agriculture), 1971.

[12] Dept. of Agr. Econ., Saga University (Hiroshi Eriguchi), *Saga Heitanchi ni okeru Nomisō Bunkai to Ogata Kikaika Kyōdō Keiei no Shūekisei* (Changing Status of Farmers and Returns on Large Scale Mechanized Co-operative Farm), 1970.

[13] Sano, Fumihiko, "Hachirō-Gata no Keiken kara Manabu" (Learnings from the experience of Hachirō-Gata), *Kikaika Nōgyō* (Mechanized Agriculture), Feb. 1971.

[14] Agr. Expt. Sta. Kumamoto Prefecture, *Experimental Record in Agricultural Mechanization,* 1971.

[15] Agr. Expt. Sta. Fukuoka Prefecture, *Survey Report in Promotion of Agricultural Mechanization,* 1971.

THE FARM MECHANIZATION PROCESS IN KOREA

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Machines for milling grains such as rice, barley and wheat were first introduced in rural Korea half a century ago. Until recent years, modern power-driven milling facilities remained the main type of machinery extensively used. Farm work related to cultivation, from plowing to threshing, continued to be done by hand implements, traditional and improved. With the surplus of labor that existed in agriculture until recently, mechanization could hardly have been expected to replace human and animal labor in farm work.

Rice farming, especially, calls for heavy labor inputs concentrated in June and October, and is dominated by peasant farmers. The fact that rice grows in paddy fields seems to contribute to limited mechanization of field work, and perhaps mechanization is not critical in rice farming.

Until recently, most improvements were in hand tools or animal-drawn implements used in such field work as plowing, leveling, weeding and spraying. The representative farm machine in Korea today is not a tractor or a combine but a power tiller.

Factors in Farm Mechanization

A new farm tool or machine is an innovation. As in the case of any other innovation, it must be technically and economically feasible and culturally acceptable before it is adopted by farmers. However, for diffusion of an innovation to occur, there must be an initiator, which can be either a private firm or government.

Generally, the process of farm mechanization is affected by both pull and push factors within and outside agriculture. The core push factor will be supply of quality machinery at reasonable prices and government assistance through financial and institutional arrangements aimed at accelerating the adoption of machines by farmers.

Table 1. Sources of Financing Farm Machinery,* 1961–70.

	1961	1963	1965	1967	1969**	1970
Total expenditures (1,000,000 won)	6.0	183.8	907.0	768.4	2,088	2,589
Gov't subsidy (%)	60	57	46	41	74	55
Credit (%)	—	4	—	40	25	11
Cash payment (%)	40	39	54	19	1	34

Source: Ministry of Agriculture and Forestry (unpublished).

* Includes power tillers, sprayers, dusters, pumps, threshers and prime motors.

** No power tillers distributed.

Because the machinery industry is still in its infancy in Korea and this farm machinery has been relatively expensive, the government has provided heavy subsidies and credit to farmers who purchase machinery as shown in Table 1.

Because farm roads and field layout have been inadequate, similar governmental help has been given to farmers in rearranging their paddy land. The February 1972 report on paddy land rearrangement gave the following totals:

As of 1945 38,138 hectares rearranged
As of 1970 149,452 hectares rearranged

The latter figure represents 12 percent of total paddy land area. Governmental funds covered 64 percent of the 12 billion won spent on this program in the decade of the 1960s. This included support from central and local governments and grain aid from the PL 480 program. Paddy land rearrangement programs have expanded rapidly in recent years. Thirty thousand hectares were scheduled for rearrangement during 1971.

The "pull" factor, or demand for farm machinery (Dm), in the early stages of farm mechanization may be conceptualized as a function of time saving (T), yield increase (Y), ratio of machinery costs (Pm) to product price (Pr), ratio of machinery costs to costs of substitutable inputs (Ps), increased ease of farm work with machinery (E), and expected psychic income from owning machinery (S):

Dm = f(T, Y, Pm/Pr, Pm/Ps, E, S)

The relative importance of each of the explanatory variables differs with time and among farms.

For instance, the effect of time saving or work simplification would be very important for grain farming in June, when transplanting rice and harvesting barley and wheat are competing for time, and in late October and November, when rice harvest and seeding barley and wheat are partly in conflict.

The yield-increasing effect may be notable in paddy areas of heavy soil where deep plowing contributes to increased yields of rice.

Real prices of power tillers, expressed in the ratio of purchasing price of machinery to rice price, have improved in favor of machinery through the government subsidy (Table 2). The relative price of motor tillers also has improved because of the rapid increase in wage rates and in the costs of plowing by cattle.

Ease of farm work with machinery and psychic income or prestige from owning a modern form of facility appear to contribute to increased demand for machinery in rural communities

Table 2. Price of Power Tiller and Government Subsidy, 1961–70.*

Year	Price of Power Tiller (6 HP)	Source of Financing		
		Gov't Subsidy	Credit	Cash
	won	percent		
1961	150,000	60	—	40
1963	140,628	50	13	37
1965	206,000	24	—	76
1967	236,500	35	51	14
1970	338,000	24	30	46

Source: MAF (unpublished).

* Price of power tiller includes four basic attachments: a trailer, an iron wheel for wet land, a rotary, and a plow. The price shown in 1970 is that of a power tiller with a water-cooled kerosene engine of 8 HP.

where conventional forms of farm implements have long been dominant.

Process of Farm Mechanization

The process of farm mechanization in Korea can be broken down into three periods: before 1960, 1960 to 1965, and since 1966.

Before 1960

With the redundant labor supply in rural Korea until the 1950s, farm mechanization was not seriously considered by farm people. Efforts were concentrated on improving hand tools for simplification of farm work.

Power machinery used in farming was limited to prime motors, barley threshers, grain polishers and water pumps. No noticeable efforts were made by the government or private firms to encourage extensive use of machinery on farms during this period. Statistics of main farm machinery owned by farmers in 1960 show 5,000 sprayers and dusters, 3,900 threshers and 7,000 water pumps.

First half of the 1960s

The first Five-year Economic Development Plan started in 1962. Power tillers were first imported in 1961.

In 1963, two firms, Daetong and Jinil, in technical cooperation with Japanese firms, produced 305 power tillers. These were distributed to selected farmers, together with 560 sprayers or dusters and 2,251 water pumps, with a heavy government subsidy.

During this period, the majority of power tillers supplied were driven by water-cooled kerosene engines of 6 HP.

To complement and encourage mechanization, an agricultural engineering training center for rural youth was first established in Kyönggi Province in 1962, with similar centers set up in each of 9 provinces in 1963. In that year 1,300 rural youths were taught to operate power tillers and given basic training in mechanics.

From 1966 to date

Since 1967, when the second Five-year Development Plan started, the agricultural labor force has steadily declined (compare Table 3). The number of farm households also has showed a decreasing trend since 1968.

Table 3. Farm Population and Indexes of Agricultural Wage Rates and Manufacturing Wage Rates, 1961–70 (1965 = 100).

	1961	1963	1965	1967	1969	1970
Farm Population (1,000 persons)	14,509	15,266	15,812	16,078	15,589	14,455
Agricultural wage rates	94	112	100	120	157	180
Manufacturing wage rates	111	102	100	125	183	211

Source: *Yearbook of Agriculture and Forestry, MAF, 1970; Economic Statistics Year Book,* Bank of Korea, 1971; and *Preliminary Report on Agricultural Census,* MAF 1971.

To cope with a short supply of labor in rural areas caused by rural-urban migration, the government has become more active in paving ways to substitute machinery services for labor. Larger amounts of credit have been extended and subsidies provided for purchasing farm machinery, paddy land rearrangement, and construction or improvement of farm roads.

For example, in 1970 the amount of government subsidies for farm machinery was 3.5 times that of 1965. At the same time, the production capacity of power tillers has increased to 15,000 a year and the total supply of power tillers went up to 4,774 in 1970, 7 times that in 1965 (Table 4 shows increases in numbers of various kinds of machines on farms).

Table 4. Numbers of Farm Machinery Available to Farmers, 1961–70.

Kind of Machine	Unit	1961	1963	1965	1967	1969	1970
Power tillers	1	30	386	1,100	3,819	9,086	12,382
Sprayers and dusters	1,000	31	88	150	243	391	494
Grain threshers	1,000	652	761	884	928	933	884
Water pumps	1,000	34	42	52	78	112	111

Source: MAF (unpublished).

Since 1966, larger-capacity motor tillers, 8 or 10 HP, have also increased in supply.

Tractors were first imported in 1967.

The Central Farm Mechanization Training Institute was created in 1969, and two farm mechanization demonstration centers were put into operation in 1970.

Use of Power Tillers by Korean Farmers

Because only a limited number of power tillers have been distributed to agriculturists through government channels, there is no significant relationship between ownership of machinery and size of farms as measured by area of crop land.

For example, according to a survey conducted by the Office of Rural Development in 1971, 66 percent of power tillers are owned on small-scale farms less than 1 hectare in size, 27 percent on medium-size farms of 1 to 2 hectares, and 7 percent on large-size farms of 3 hectares or over. Furthermore, 81 percent of power tillers are in areas where paddy fields are not yet rearranged.

A survey made by the Agricultural Economics Research Institute (AERI) on power-tiller owning farms, including ten grain farms, ten fruit farms, and eight livestock farms (seven dairy farms and one poultry farm) in 1971 indicates some features and consequences of using power tillers.

Intensive use of power tillers all year round

The total hours of operation for a power tiller on the different types of farm in 1970 were 539 hours on grain farms, 812 hours on fruit farms, and 1,292 hours on livestock farms. (The average area of grain farms was 23 tanbo (=2.3 hectares), that of fruit farms was 30 tanbo, and that of livestock farms was 88 tanbo. The average dairy farm kept 21 dairy cattle, and the poultry farm had 8,000 chickens.)

In the case of crop farms of small area, 60 percent of the operating hours were for custom plowing or transportation work. A comparison of operating time and costs between power machinery and conventional methods for various operations on these farms is shown in Table 5.

No significant correlation was found between hours of home farm use of a power tiller and the total productive man work

Table 5. Comparison of Efficiency and Current Costs Between Power Machinery and Conventional Tools by Types of Farm Work.

Type of Farm Work	Time required (A)	Time required (B)	Time required $\frac{(A)}{(B)} \times 100$	Current cost (A)	Current cost (B)	Current cost $\frac{(B)}{(A)} \times 100$	Man and animal power required for traditional practice
	hours/tanbo		percent	won/tanbo		percent	
Plowing							
Paddy land	5.0	2.5	200	900	682	76	1 man + 1 animal
Upland	1.4	0.7	200	250	191	76	same
Pasture land	3.3	1.3	254	595	355	60	same
Spraying:							
Fruit trees	31.0	6.0	517	2,790	1,638	59	1 man
Paddy rice	6.0	1.3	462	540	355	66	same
Pumping:							
Rice paddy	1.0	0.5	200	180	135	76	2 men
	hours/10 bags			won/10 bags			
Threshing:							
Paddy	5.0	4.0	125	3,150	2,092	66	7 men

Source: Agricultural Economics Research Institute (unpublished).

Notes. (A) = Conventional tools (B) = Power machinery

Table 6. Percentage Distribution of Home Farm Use of Power Tillers on Various Types of Farms.

Type of farm	Plowing	Spraying	Threshing	Transporting	Generating electricity	Other
Crop	41	–	41	–	–	18
Fruit	–	20	–	35	20	25
Livestock	–	–	–	60	21	19

Source: Agricultural Economic Research Institute (unpublished).

units of individual farms (r=0.272).

A study made on the use of power tillers (6 HP) in the Honam plain area in 1965 by AERI showed that average per hour revenue from custom work was 1,950 won, and the break-even point was 500 hours of operation a year. Because the motor-tillers could be used for 54.5 hours per hectare of crop land, approximately 10 hectares were required for economic use of a power tiller.

That power tillers are intensively used on most farms for various purposes may be because the costs of motor tillers and interest rates are high, while the rates of return to machinery services are still low in rural Korea. These facts also reflect the large potential demand for farm machinery services even though current demand for machinery is quite restricted because of limited capital available and structural constraints prevalent in the rural sector.

Multi-purpose use of power tillers

The power tiller has been used for various purposes on farms, such as plowing, leveling, threshing, spraying, pumping, transportation and generating electricity (Table 6). Transportation and generating electricity are important uses of power tillers on commercial farms, since motor vehicles and electricity are still scarce.

Diversification of farm management

Since power tillers enable agriculturists to carry out field work more efficiently, new enterprises can be introduced. For instance, out of a total of 28 sample farms, 2 grain farms increased barley plantings by 5 to 7 tanbos, and one fruit farm added a poultry enterprise (1,200 poultry).

Actually, power tillers have been intensively used for plowing and threshing for barley farming in the southern provinces, and a substantial portion of demand for custom work thus far has been for these operations.

No adaptive changes in cropping technology

The basic features of crop farming with hand-operated tools seem not to have changed with the introduction of power tillers or other farm machinery. It will take time to develop adaptive cropping or field work schemes appropriate to the use of power tillers or tractors instead of hand-operated implements.

Need for and Problems of Farm Mechanization Felt by Farmers

As shown in Table 7, Korean farmers adopted power tillers primarily to save labor or to reduce the degree of hardship of manual labor.

As a matter of fact, farm work with traditional tools in rural Korea has been so hard that few educated young men want to stay on farms without labor-saving devices.

The concern over the hardship of farm work seems to reflect a change in cultural values stemming from urban culture and at odds with the traditional value system which valued hard work.

Table 7. Reasons for Purchasing Power Tillers by Korean Farmers.

Reason	Percent
Reduce the hardship of manual labor	32
Solution to labor shortage	29
Diversification of farm organization	29
Other	10

Source: Agricultural Economics Research Institute (unpublished).

Table 8. Non-Economic Gains Expected from Owning Power Equipment.

Expected Gain	Percent
Prestige due to conspicuous ownership	41
Increased leisure time	45
Other	14

Source: Agricultural Economics Research Institute (unpublished).

Table 9. Problems Felt by Power Tiller Users.

Problem	Percent
Fields not rearranged or poor farm roads	34
Expensive parts	21
Far away from repair shops	16
Poor skill in operating machines	12
Frequent break-downs	6
Short supply of attached equipment	5
Insufficient horsepower	5
Other	1

Source: Office of Rural Development (unpublished).

Table 10. Sources of Technical Know-how and Skills in Operating Motor Tillers.

	Self-learning	Neighbors & relatives	Manufacturers
Percent	32	25	43

Source: Agricultural Economics Research Institute (unpublished).

Furthermore, this motive may reflect an upward shift of the marginal disutility curve of family labor due to increased income in the Korean farm sector. This is why many purchased power tillers in order to reduce the hardship of farm work, and many expected to have more leisure time by having power tillers (Table 8).

The problems reported by farm machinery users to Office of Rural Development in 1970 are listed in Table 9, which shows that 37 percent of the problems related to the costs and quality of machinery.

Poor after-service provided by the manufacturers of farm machinery has been criticized. Repair service is very expensive. For instance, a survey showed that 8 percent of the purchase price of a motor tiller was spent each year for repairs, which is considerably higher than the 3.5 to 5 percent in developed countries.

This may be partly due to users' lack of skill in operating machinery. The survey conducted by Agricultural Economics Research Institute in 1971 indicated that only 14 percent of farmers who purchased power tillers had acquired skill in operating these machines before they actually used them in fields, and 29 percent of the purchasers did not have even a basic knowledge of how to operate the tillers (compare Table 10).

This problem of technical know-how is also reflected in a recent survey conducted by Office of Rural Development, in which 23 percent of farmers owning motor tillers listed "ease in operation" as the prime criteron for selecting the type of tiller.

Concluding Remarks

Farm mechanization has become urgent in rural Korea as a solution to a growing labor shortage. It is felt, however, that effective actions should be taken not only to increase the supply of quality farm machinery but also to accelerate improvements in physical infrastructure and technologies on farms.

Use of farm machinery improves income opportunities for the farmer through diversification of farm operations and increases opportunities for off-farm earnings. It furthermore tends to create new needs for innovation, organizational and technological, not only in agricultural production but also in the marketing system. Thus systematic, enlarged efforts are called for in studying the problems, economic and technological, of farm mechanization in rural Korea.

MECHANIZATION IN KOREAN FARMING: PRESENT STATUS, OBSTRUCTING FACTORS, AND REMEDIAL MEASURES

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In this paper we first review the present status of mechanization in Korean farming, pointing out the limited progress so far achieved. We then analyze a number of factors holding back mechanization. Finally, we suggest ways in which these obstructions may be overcome, and present a number of concrete suggestions on policies and programs for achieving this.

Current Status of Farm Mechanization

Farm mechanization commenced only recently in Korea. Large farm equipment such as four-wheel tractors and combines are virtually unknown. At the end of 1968, only 108 four-wheel tractors were in use.

However, there has been, particularly in the last four years, a significant increase in the numbers of small power equipment in use on farms. The rate of increase in the number of power tillers has been above 40 percent each year since 1962.

Nevertheless, the absolute level of mechanization is still low, with only 12,882 tillers in use in 1970, an average of one tiller for each 193 farm households. If we compare the number of power tillers in use with the number of farm households having farms of one hectare or more, we find only one tiller per 65 households. (About 66.4 percent of farm households have farms of less than one hectare.)

The use of power water pumps and power sprayers and dusters is considerably more widespread, but there is still only one water pump, for example, per 43 farm households.

Comparison of farm equipment per 1,000 farm households in Japan and Korea is very revealing. Korea, for example, had only one percent as many tractors and tillers per 1,000 farm

Table 1. Farm Equipment Per 1,000 Farm Households in Japan and Korea.

Type	Japan 1967 (A)	Korea 1970 (B)	Ratio (B/A)
			(percent)
Power tillers and tractors	568	5.2	0.9
Power sprayers	176	4.7	2.7
Power threshers	608	10.7	1.8

Source: Korea Farm Mechanization Research Institute, *Yearbook*, 1969.

households in 1970 as Japan had in 1967. The ratio for other farm power equipment is similar (Table 1).

In spite of significant increases in use of farm equipment, the absolute volumes have not been high enough to raise the percentage of the value of farm equipment in the total assets of farm households. The 1970 Farm Household Economic Survey reported that large implements, including machinery, constituted only 0.5 percent of the total assets of the Korean record-keeping farm households surveyed in 1969.

Changes in prices of farm assets may obscure the increased use of equipment. However, in comparison with Japan, where the value of farm equipment is nearly 20 percent of farm assets, the level of mechanization in Korea is low.

Korea also has low average expenditure on farm implements compared with Japan. In cost of production data for the two countries, farm implement expenditure in Korean rice production is a small fraction of that in Japan. The same is true for other crops such as barley, wheat, and sweet potatoes.

Another revealing comparison is between the ratios of farm implement and wage costs in farm expenditure in Korea and Japan. Japan's farm implement expenditure in 1968 was 26.0 percent of total farm expenditure, whereas that in Korea averaged only 2.9 percent. In contrast, farm wage expenditure in Japan was only 3.6 percent of farm expenditure, whereas in Korea it was 28.2 percent (Table 2).

Table 2. Comparison of Farm Implement and Wage Expenditure in Korea and Japan, 1968.

Country	Farm Expenditure				
	Total	Farm implements		Wages	
		Amount	Percent of total	Amount	Percent of total
	(won)	(won)		(won)	
Japan	399,100	103,700	26.0	14,200	3.6
Korea					
Average	38,265	1,092	2.9	10,793	28.2
By size of farm (chongbo*)					
0.2–0.5	15,352	309	2.0	3,212	20.9
0.5–1.0	26,530	678	2.6	5,696	21.5
1.0–1.5	44,234	1,360	3.1	11,312	25.6
1.5–2.0	68,866	2,889	4.2	19,572	28.4
Over 2.0	104,812	2,195	2.1	43,130	41.4

* 1.0083 chongbo = 1 hectare

Clearly, Korean agriculture depends mostly upon hand labor. Farm management in the Korean farm economy is not oriented to mechanization. Moreover the lack of farm equipment is reflected in the low level of farm labor productivity.

Korean agriculture has barely begun to mechanize. Nevertheless there is clear evidence that farmers are recognizing the advantages of some forms of mechanization. Diffusion rates of such machinery as power tillers, power threshers, and power sprayers and dusters, though still very low compared to Japan, are increasing year by year.

The trend toward increased use of small power equipment suggests that changes are taking place in the agricultural sector which are making mechanization more attractive and presumably more profitable than during earlier years. Therefore, let us turn next to analysis of factors obstructing this development.

Factors Obstructing Farm Mechanization in Korea

Small size of farms

The small size of Korean farms has prevented farmers from utilizing large farm equipment efficiently and from accumulating enough savings to pay the purchase price of relatively expensive farm equipment. While the percent of farms under one chongbo in size has declined from 73 percent in 1960 to 66.4 percent in 1969, the fact remains that about two thirds of all farmers cultivate less than one hectare. Only 1.6 percent of the farmers cultivate more than 3 hectares (Table 3).

The Agricultural Economics Research Institute has estimated that only farmers cultivating two hectares or more of land are financially capable of purchasing farm machinery. Moreover, machinery prices, in terms of farm output, are two to three times as high in Korea as in Japan. If these estimates are correct, then only seven percent of Korea's farmers are financially capable of saving enough to purchase farm equipment.

Table 3. Distribution of Farm Households by Size of Farm.

Size of farm	1960		1965		1969	
chongbo	Number of farm households	Percent of total	Number of farm households	Percent of total	Number of farm households	Percent of total
0.0–0.5	1,008,624	42.9	900,840	35.9	842,171	33.9
0.5–1.0	706,689	30.1	793,864	31.7	807,442	32.5
1.0–2.0	485,933	20.7	643,305	25.7	667,617	26.8
2.0–3.0	141,371	6.0	139,599	5.6	129,330	5.2
Over 3.0	6,889	0.3	29,291	1.1	39,421	1.6

Source: Ministry of Agriculture and Forestry.

Low wage rates in rural areas

Along with other characteristics of farming in Korea, low wage rates relative to the rest of the world have tended to discourage Korean farmers from introducing imported farm equipment and encouraged continuation of labor intensive technology. As domestic wages rise without offsetting increases in the exchange rate, duties, or foreign prices, imported machinery becomes more and more profitable to adopt. A simple comparison of farm wages in Korea and the United States is shown in Table 4.

Similarly, low farm wage rates relative to farm equipment prices delay the introduction of locally produced farm equipment. Since, 1965, however, farm wage rates have increased much faster than prices of either imported or domestically produced equipment, which is making mechanization more and more profitable.

Table 4. Farm Wages in Korea and the United States, 1965–70.

Year	Korea: Male wage/day[1]	Korea: In U.S. dollars[2] (A)	U.S. wage per day[3] (B)	Korea/U.S. (A/B)
				(percent)
1965	Won 222	$ .82	$ 7.60	10.8
1966	256	.95	9.00	10.6
1967	307	1.12	9.90	11.3
1968	381	1.13	10.90	12.5
1969	463	1.60	10.30	15.5
1970	585[4]	1.89	11.30[5]	16.7

Source: *Agricultural Cooperative Monthly Survey*, May 1970, and *Statistical Abstract of the United States.*

[1] Adult male, in cash and kind

[2] Converted at annual average exchange rate

[3] Without board and room

[4] July

[5] April

Fragmentation of holdings

A third factor obstructing the development of farm mechanization is the fragmentation of farms, irregularity of farm fields, and lack of farm roads. Accentuating the effect of small size of farms, the fragmentation of each farmer's holdings (Table 5) causes waste of time and of fuel in moving farm machines to the working place. Such a situation prevents efficient use of farm machines or equipment.

Table 5. Fragmentation of Cultivated Lands by Farm Size.

Farm size in chongbo	Average number of parcels	Average size of parcels	Number of parcels maximum
		pyung*	
Less than 0.3	1.8	500	6
0.3–0.5	3.0	400	11
0.5–1.0	4.4	500	14
1.0–1.5	6.2	600	17
1.5–2.0	7.7	670	16
2.0–2.5	9.3	700	17
More than 2.5	8.4	850	14

Source: National Agricultural Cooperative Federation.
* 3,000 pyung = 1 chongbo.

Not only are holdings fragmented, the separate parcels are often scattered at considerable distances from the homestead (Table 6).

Lack of rural capital accumulation

A fourth factor obstructing the development of farm mechanization is lack of rural capital accumulation. Both the high purchase cost of machines and the high maintenance cost of machine utilization make it difficult to introduce farm machinery and equipment in peasant farms.

Table 6. Numbers of Parcels by Distance from Farm Homestead.

Distance	Number of parcels of paddy	Percent-age	Number of parcels of upland	Percent-age
meters				
Less than 100	116	3.6	249	10.6
100–200	381	11.9	349	15.0
200–300	419	13.1	345	14.7
300–400	412	12.9	323	13.7
400–500	266	8.3	185	8.0
500–600	394	12.3	234	10.0
600–700	209	6.5	141	6.0
700–800	200	6.2	102	4.4
800–900	152	4.7	92	3.5
900–1,000	51	1.6	33	1.5
More than 1,000	601	18.9	295	12.6
Total	3,201	100.0	2,348	100.0

Source: National Agricultural Cooperative Federation.

Labor situation in rural areas

Korea is characterized by disguised unemployment in rural areas. Development of manufacturing and the other non-agricultural sectors has not resulted in much migration of labor out of the agricultural sector except to industrial urban areas. This has absorbed a small proportion of the redundant farm labor supply (Table 7).

According to these data, the economically non-active population less than 14 years old decreased 1.7 percent. Persons older than 60 increased 0.3 percent. Total farm population decreased about 2.0 percent.

Thus Korea is still a labor surplus economy with large amounts of redundant labor in the agricultural sector. Except in the peak-labor seasons of spring planting and fall harvest, Korean agriculture has a labor surplus most of the year. This is another factor obstructing introduction of farm machinery.

Table 7. Changes in Farm Population, by Age Group, 1968 to 1969.

Item	Less than 14 years	14–19	20–49	50–59	More than 60	Total
	··· thousand persons ···					
1968	6,368	2,033	5,059	1,342	1,106	15,908
1969	6,262	1,961	4,945	1,312	1,109	15,589
Change	–106	–72	–114	–30	+ 3	– 319
	··· percent ···					
Rate of change	–1.7	–3.5	–2.3	–0.22	+0.3	–2.0

Source: Ministry of Agriculture and Forestry.

Shortage of credit

While the commercial banks in Korea have an extensive network of branches throughout the country, they, like commercial banks elsewhere in the world, do not find lending to individual farmers very attractive and lend virtually nothing to them.

There are several understandable reasons. Commercial banks specialize in relatively large commercial and industrial loans in urban areas. They do not have the expertise or experience for appraising farm loans. This constitutes an impenetrable credit barrier between the farmer and much of the supply of loanable funds, and compels most farmers to rely on the National Agricultural Cooperative Federation (NACF), which lends through the *gun* agricultural cooperatives.

Unfortunately, NACF funds for farm mechanization have been limited because the available credit has been devoted mostly to short-term purposes and because the total farm credit supply historically has been modest.

Lack of technicians to operate and repair farm machines

Technical knowledge and skill in operating farm machinery greatly affects the efficiency of use of machinery, the operating cost, the durable life of the machines, the prevention of breakdowns, etc. Korea lacks qualified technicians for operating and repairing farm machines. Farmers do not know the technique of machine operation and repair. This is still another impediment to development of farm machinery in Korean farming.

Farmers' psychological attitudes toward mechanization

Korean farming depends upon family labor, and most farmers do not employ hired labor. In this situation, the feasibility of farm mechanization is limited unless it can be used by family labor. A further obstruction to introduction of farm implements is that traditional methods of farming do not include use of farm machinery or equipment.

Lack of development of the farm implement manufacturing industry

There is limited domestic production of farm machinery. Two companies produce tillers—the Dae Dong Industrial Company, Ltd., and the Chinil Machinery Company. The latter company, recently associated with Yanmar Diesel Co. of Japan to create the Hanil Farm Tools Co., started production of a diesel engine tiller in 1970, and received an order for 1,667 8-HP tillers at ₩362,000 each from the 1970 budget of NACF. The

Table 8. Domestic Production of Farm Tillers, 1970.

Producer and type	Quantity	Value	
		Thousand won	Thousand U.S. dollars
Chinil Machinery Co.			
8-HP, ₩ 362,000	1,667	603,454	1,915.7
Dae Dong Industrial Co.			
8-HP ₩ 314,787	500	157,393	499.7
10-HP ₩ 337,926	1,414	477,827	1,516.7
8-HP ₩ 314,787 (direct sales)	580	182,576	579.6
Total	4,161	1,421,250	4,511.9

Source: Unpublished data of NACF.

Dae Dong Industrial Company supplied 1,914 kerosene engine tillers to NACF in 1970—500 8-HP and 1,414 10-HP tillers. Dae Dong also sold 580 tillers direct to farmers (Table 8). (About 93 percent of the Dae Dong tiller is made of domestic and 7 percent of imported components.)

In total, local producers supplied 4,161 tillers in 1970 with a value equivalent to $4.5 million.

Ways to Overcome Obstructions to Farm Mechanization

Surplus labor in relation to land resources

Generally, farm mechanization develops under labor-shortage conditions. Such a situation encourages joint use of farm machinery and equipment and cooperative labor utilization. Korea is still a labor surplus economy with large amounts of redundant labor in the agricultural sector. However, the high rate of economic growth, particularly in manufacturing but also in other non-agricultural sectors, is resulting in a migration of labor out of the agricultural sector.

Farm mechanization is labor saving. It frees labor to move to alternative areas of higher productivity such as manufacturing, or for labor-intensive agriculture such as sericulture and horticulture or livestock.

Difficulty in implementing joint production systems

The small size of farms and lack of capital have prevented introduction of higher technology in Korean agriculture. However, if small farmers join together, they can get the advantages of large-scale economy through common use of modern farm machinery.

Thus, joint production systems make possible intensive use of more capital and increase of labor productivity. They permit expansion of size of farm operating units, introduction of efficient farm machinery, application of higher technology, rationalization of labor organization, etc. In other words, joint production systems help solve the problems of small size of farms, management, capital, labor organization, and technology.

The development of joint production systems for farm mechanization has to be based on farmers' mutual understanding and cooperation. Farmers do not know much about the purpose or idea of joint production systems. Therefore, farmer education is urgently needed for development of such arrangements.

In subsistence farming, farmers consider land as their only means of living, to be passed on to succeeding generations. Therefore, each farmer has a feeling of attachment to his land. This is a further restricting factor in implementation of joint production systems. However, this could be overcome by education of farmers and demonstration of advantages of joint production through farm mechanization.

Land rearrangement

Land rearrangement must be carried out for the efficient utilization of farm machinery and equipment. In implementing land rearrangement, many problems arise regarding individual farmers' interests in type and area of land, rural roads, etc. Therefore, land rearrangement must be carried out on the basis of common interest and mutual understanding. In this case, also, farmer education is needed for implementation of land rearrangement.

Establishment of farm equipment utilization associations

Large-size farm equipment is needed for efficiency in farm mechanization. In fact, most small farmers can not buy farm machinery because of limited financial resources for purchasing it and limited area for using it. Therefore, several farmers should cooperate in purchase and use of farm equipment.

In carrying this out, establishment of farm equipment utilization associations is needed to implement farm mechanization. Farm equipment utilization associations should function through diffusion of knowledge and techniques for use of farm equipment, provision of repair service, training centres in farm equipment operation, recommendation of farm equipment, etc. Thus, farm equipment utilization associations would perform a significant function in implementing Korean farm mechanization.

Government subsidy or loan for the purchase of farm equipment

Purchase of farm machinery and equipment can be encouraged through government subsidy or loans. In the past, subsidies and

Table 9. Sources of Funds for Financing Farm Equipment, 1962–68.

Year	Subsidy		Loan		Cash		Total	
	Amount	Percent	Amount	Percent	Amount	Percent	won	U.S. dollars
	(1,000 won)		(1,000 won)		(1,000 won)		(1,000 won)	($1,000)
1962	91,396	57.8	—	—	66,821	42.2	152,817	502.3
1963	103,864	56.5	7,737	4.2	72,161	39.3	183,762	583.4
1964	47,638	41.8	—	—	151,427	58.2	199,065	632.0
1965	417,304	46.0	—	—	489,744	54.0	907,048	2,879.5
1966	96,807	37.5	—	—	157,134	60.9	258,142	819.5
1967	305,377	39.7	306,995	40.0	147,948	19.5	768,442	2,439.5
1968	606,047	30.7	511,196	28.5	677,788	37.8	1,795,031	5,698.5

Source: Ministry of Agriculture and Forestry.

loans have been small. In recent years, NACF has introduced a substantial loan program for farm buyers of equipment. The combination of a 30 percent subsidy and a 28 percent loan was accompanied by a substantial increase in the quantity of farm equipment purchased in 1968, more than double that in 1967 (Table 9).

In 1970 power tillers were given a smaller (23 percent) subsidy and farmers were granted loans for 30 percent of the price (Table 10). The cash payment for power tillers was higher than for any other type of equipment.

A heavy burden of cash payment by farmers reduces substantially the capacity of farmers to purchase farm equipment. Therefore, the government should try to increase subsidy or loan funds in order to increase the capacity of farmers to purchase equipment for mechanization in Korean farming.

Conclusion

The needs for farm machinery will be changed considerably because of: (1) the out-migration of rural population into urban areas, (2) greater reliance on power sprayers and threshers, and (3) the need for mechanized tilling and transportation equipment. As out-migration continues and crop yields increase there will be an additional need for mechanical grain drying as well as harvesting equipment.

Out-migration of labor from agriculture and substitution of labor-saving machinery for the departed labor will raise land and labor productivity and will reduce production cost per unit of output relative to more labor-intensive methods.

Because farm implements are costly relative to average farm income, the need for credit to finance them is crucial to any effort toward mechanization. Even a continuation of current trends in the demand for farm implements requires substantial loans. There are no official assessments of demand for farm implements in the near future, but farmers are known to face shortages of labor for planting and harvesting the rice and barley crops.

The draft animal is used primarily as a power source and also serves as the primary source of beef. With the very strong demand for beef it would be more economical to develop a true beef-type farm animal rather than rely on slow-growing work cattle for meat. Concurrently, a more efficient source of power could be developed. If the tiller proves to be clearly a more economic source of power than draft animals, the demand for tillers could grow very rapidly in the near future. This would require more joint or cooperative systems in conjunction with farm mechanization.

An indication of the increased competitiveness of mechanical power sources is suggested by data showing rapid increases in the costs of farm labor and draft animals, which have more than double since 1965 (Table 11).

These figures suggest that benefits from introduction of labor-saving equipment have more than doubled since 1965. Thus, farm mechanization can be economically feasible given certain underlying cost relationships. A farm implement becomes economically feasible when the costs associated with mechanization become equal to or less than the costs associated with the traditional methods.

Table 11. Cost of Farm Wages and Draft Animals, 1965–70.

Year	Farm wages & charges per adult male/day	Index (1965 = 100)	Draft animal cost	Index
	won		won	
1965	221	100.0	40,699	100.0
1966	256	115.8	48,094	118.2
1967	307	138.9	61,553	151.2
1968	381	172.4	79,487	195.3
1969	463	209.5	85,178	209.3
1970	585*	264.7*	94,073**	231.1**

Source: NACF, *Agricultural Cooperative Monthly Survey.*

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** October

GOVERNMENT POLICIES PROMOTING FARM MECHANIZATION

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Farm mechanization is generally conceived as necessary for agricultural modernization. As an economy becomes more and more industrialized, the degree of farm mechanization will be intensified.

Owing to differences in initial endowment and stage of economic development, the initiation and intensity of farm mechanization vary among countries. Farm mechanization is of vital importance to the development of agriculture and the economy as a whole when labor becomes a scarce resource and surplus labor no longer exists in the agricultural sector.

There is a very close relationship between the degree of farm mechanization and the productivity of agricultural labor. The intensification of farm mechanization can help to raise the productivity of agricultural labor.

Background of Mechanization Policy in Taiwan

The agricultural production of Taiwan has increased steadily through the improvement of production techniques and the increased use of resource inputs. Technical improvement in Taiwan has been essentially in biological aspects; there has been little improvement in mechanical aspects. Evidence of this is the great number of superior varieties of crops and livestock that have been developed and the very rapid increase in such capital inputs as fertilizer, pesticides, and feed, while the input of farm machinery and tools has not expanded substantially.

Presently, farm machinery and tools constitute only 3.5 percent of total capital input in Taiwan agriculture, much less than the corresponding figure of 30 percent for the period 1952–61 in the United States.[1] Though farm mechanization has been promoted in Taiwan for two decades, its progress has been relatively slow.

Table 1. Indicators of Structural Change of Taiwan's Economy, 1952–70.

Year	Net Domestic Product			Population		Employment	
	Agricultural	Industrial	Other	Agricultural	Non-agricultural	Agricultural	Non-agricultural
				(unit: percent)			
1952	35.7	17.9	46.4	52.4	47.6	61.0	39.0
1961	31.3	24.9	43.8	49.0	51.0	55.8	44.2
1962	29.0	25.7	45.3	48.0	52.0	55.3	44.7
1963	26.6	28.0	45.4	47.2	52.8	54.5	45.5
1964	27.7	28.2	44.1	46.1	53.9	54.2	45.8
1965	27.0	28.2	44.8	45.4	54.6	53.7	46.3
1966	25.7	28.6	45.7	44.7	55.3	53.0	47.0
1967	24.5	29.4	46.1	44.7	55.3	49.4	50.6
1968	23.8	30.3	45.9	44.0	56.0	49.4	50.6
1969	20.8	32.0	47.2	43.0	57.0	45.3	54.7
1970	19.2	32.0	48.8	40.9	59.1	44.5	55.5

Source: Council for International Economic Cooperation and Development, *Taiwan Statistical Data Book*, 1971.

The economic structure of Taiwan has experienced drastic change in recent years which has brought about the need for acceleration of mechanization. Therefore, farm mechanization is considered an essential policy measure for agricultural development in the future.

Farm mechanization involves not only technical matters, but also social, economic and institutional elements. The problems of farm mechanization can be tackled from various aspects; this paper is intended to investigate farm mechanization in Taiwan from the viewpoint of government policy. Specifically, the purposes of this paper can be listed as follows:

1. To analyze the structural change of the economy and the need for farm mechanization.
2. To understand the problems of farm mechanization and to ascertain the ways for solving them.
3. To review the experience of farm mechanization in Taiwan with special emphasis on government policies.
4. To consider policy and strategies for accelerating farm mechanization.

Changes in Economic Structure and the Need for Farm Mechanization

The structure of Taiwan's economy has showed tremendous changes since the implementation of the successive four-year economic development plans beginning in 1953.

During the period 1952–70 industrial input, which includes manufacturing, mining, construction, and electricity, increased by 992 percent, an annual rate of increase of more than 14 percent, while agricultural output increased by 137 percent, not quite 5 percent per year. Consequently, the share of agricultural in net domestic product decreased from 36 percent to 19 percent, and the proportion of industry rose from 18 percent to 32 percent.

Under the rapid expansion of industry, the proportion of agriculture in total population declined from 52.4 percent in 1952 to 40.9 percent in 1970, and the percentage of agricultural workers in total labor force dropped from 61.0 to 44.5 (Table 1).

The year 1965 is usually taken as the turning point in the transformation of Taiwan's economy. Before 1965 the economy was predominantly agricultural; since then industry has become the leading sector.

Amid the transformation of the economy, the pattern of Taiwan's agricultural development has also changed significantly.[2] Changes in output, input, and productivity of Taiwan's agriculture can be illustrated by dividing the whole period into two phases: the periods 1952-64 and 1965–70.

Agricultural output increased faster in the first period, while total agricultural inputs showed greater increase in the second period. The expansion of agricultural output was achieved by increase of labor and crop area in Period I and by a large increase in capital inputs in Period II.

By and large, the input increases in the latter period were in such modern inputs as chemical fertilizers, pesticides, concentrated feeds, and machinery and implements. In consequence, the composition of total agricultural inputs changed greatly: the relative importance of land and labor sharply declined. Capital inputs now have become decisive to the increase of agricultural output.

The change in agricultural development pattern and economic structure has implications for farm mechanization. In the early stage of economic development a farm labor surplus existed, because agricultural population at that time occupied a lion's share of the total population and the industrial and commercial sectors were underdeveloped.

Under such conditions, and with limited cultivated land, the only possible way of utilizing the labor force was to increase rural employment opportunities so as to enhance agricultural productivity and to achieve economic development. Labor-intensive farming techniques contributed greatly to the increase of productivity of land and labor.[3] At that stage, implementation of farm mechanization was not urgently needed.

Recently, as a result of rapid industrialization and expansion of non-agricultural sectors, non-farm employment opportunity has increased continuously, the migration of rural labor from agriculture has increased, and Taiwan's agriculture has been experiencing a labor shortage for the first time in its history.

Table 2 shows that total employment in Taiwan increased from 3,689,000 in 1966 to 4,546,000 in 1970, an annual growth rate of approximately 5 percent. The highest annual rate, 9.2 percent, occurred in manufacturing industry, while agricultural employment showed no consistent trend in the last few years.

In fact, the figures for agricultural employment in Table 2 may be overestimates. According to a study by H.T. Oshima and W.H. Lai, the total employment in agriculture was 1,480,000 in 1965 and decreased to 1,387,000 in 1969, a decrease of nearly 100,000 within five years.[4] During the same period, the real wage rate in agriculture went up by 47 percent as a result of decrease in the agricultural labor force. The increasing pressure of labor shortage in agriculture and the high wage rate create an urgent need for farm mechanization.

Owing to labor shortage, high production cost and unfavorable terms of trade for agriculture, the increase in productivity of agricultural land and labor has slackened. The slow increase we now face in agricultural production will influence the price and wage level of the economy and will retard industrial investment and output. Furthermore, without improvement of the agricultural structure and development pattern, it will be very difficult to transfer resources from agriculture to industry, and the development of the national economy will be hindered.

Under the present situation, farm labor is in shortage during the peak season. However, from the viewpoint of labor productivity and long-run labor demand of various sectors, farm labor is still a redundant factor.

To undertake farm mechanization may be a way to solve the dilemma. The increased use of farm machines will save labor, reduce cost, and increase the production of agriculture. Farm mechanization, therefore, is an effective means to increase agricultural labor productivity and improve farmers' income.

Acceleration of farm mechanization may also make it possible to release more labor for the use of other economic sectors and mitigate the rise of wage rates.

According to the Long-Term Economic Development Plan of Taiwan, Republic of China (1971–80), Gross Domestic Product will increase at a rate of 8.5 percent annually and the growth rates for agriculture and industry will be 3.6 percent and 11.1 percent, respectively. To keep pace with this rapid economic

Table 2. Labor Employment by Industry, Taiwan, 1966–70.

Year	Total	Primary Industry (Agriculture)	Secondary Industry			Tertiary Industry			
			Total	Manufacture	Other	Total	Commerce	Service	Other
				(unit: 1,000 persons)					
1966	3,689	1,613	877	647	230	1,199	425	559	215
1967	3,973	1,705	997	744	253	1,271	497	563	211
1968	4,159	1,652	1,032	736	296	1,476	606	645	225
1969	4,434	1,728	1,171	834	337	1,535	628	679	228
1970	4,546	1,672	1,284	928	356	1,590	667	668	255

Source: Taiwan Provincial Labor Force Survey and Research Institute, *Quarterly Report on Labor Force Survey in Taiwan,* Republic of China, Jan. 1971.

growth, total employment will increase at an annual rate of 3.4 percent—4.94 percent in secondary industry, 5.99 percent in tertiary industry, but −0.83 percent in agriculture. In other words, agricultural employment will be reduced by 136,000 persons within ten years. Hence, farm mechanization is considered an essential policy measure to promote economic development.

Current Situation and Problems of Farm Mechanization in Taiwan

Historical background and current situation

The history of farm mechanization in Taiwan may be traced back two decades.[5] Soon after World War II, the United Nations Relief and Rehabilitation Administration donated a great amount of farm machinery to the Chinese Government in an attempt to solve the problem of shortage of draft cattle.

These machines were later transferred to the Board of Trustees for Rehabilitation (BOTRA). Under BOTRA, several sub-organizations were established, one of which was the Taiwan Agricultural Machinery Operation and Management Office (AMOMO).

AMOMO owned a considerable amount of farm machinery, including tractors, pumping machines, combines, plate mills, well-drilling rigs, farm implements, and equipment for repair and maintenance of farm machines. Several tractor-farming teams, well drilling teams, and pumping stations were set up by AMOMO to serve farmers.

AMOMO demonstrated tractor farming, trained farmers to operate tractors, and tried to sell tractors with attachments to farmers on installments at cost price. The extension of tractors for use by farmers failed, for two reasons: (1) The average farm size was too small and farm land was fragmented, (2) The cost of using a tractor was too high to substitute it for human and animal labor.

Nevertheless, it was found practicable for the Taiwan Sugar Corporation (TSC) to adopt tractor farming. TSC owned hundreds of big sugar cane farms. Thus, when BOTRA was dissolved in 1950, AMOMO was merged into TSC.

Great progress has since been achieved in sugarcane field mechanization. At present, TSC owns 465 tractors of various types, with all kinds of implements, to cultivate 40,000 hectares of cane farms. Field operations are almost entirely mechanized except for planting and harvesting.

The major cane field mechanical operations are plowing, harrowing, ridging, softening the bed, opening of planting furrows, application of fertilizers and compost, cultivating, weeding, hilling, sub-soiling, green manure seed drilling, turning under of green manure, spraying chemicals, ratoon cane off-barring, stubble shaving, and so on. For saving labor and cost, combined implements are adopted and several operations are performed with one tractor run. TSC has made a number of experiments with mechanical planting and harvesting, and the results are quite satisfactory. Therefore, the goal of full mechanization in TSC cane fields is expected to be reached in the foreseeable future.

As for general farming, an experiment with power tiller operations began in 1955 and the extension of power tillers was initiated by the Joint Commission on Rural Reconstruction (JCRR) in 1958. There were only 239 power tillers in 1958, but the number increased to 28,292 in 1970, one tiller for every 31 farm households. (Annual data on numbers, origin, and sizes of power tillers, numbers of draft cattle, and numbers of other types of farm machinery are given in the paper by Y.T. Wang, Tables 2 and 3, pages 221–22.

The progress in extension of power tillers before 1965 was relatively slow because of the surplus farm labor and low wage rate. Owing to the increasing pressure of labor shortage, the number of power tillers has expanded at a rate of nearly 4,000 per year during the last few years. With the increase in power tillers there has been a decrease of more than 10,000 head of draft animals per year.

In the earlier stages, power tillers were mostly imported from Japan. As a result of development of the farm machinery industry in Taiwan, power tillers are now mostly locally made.

There are four tiller manufacturing firms in Taiwan: China Agricultural Machinery Company, New Taiwan Agricultural Machinery Company, Mitsubishi Agricultural Machinery Company, and Precious Island Agricultural Machinery Company. They produce about 4,500 power tillers annually, which is only two thirds of their production capacity.

Another apparent tendency worth mentioning is the increase in power of tillers. The proportion of tillers with over 8 HP was only 26.54 percent of the total in 1960; it increased to 58.25 percent in 1969.

In addition to power tillers, the numbers of other farm machines and implements have also increased. Power sprayers increased from 317 in 1960 to 17,820 in 1970; hand sprayers and dusters from 114,953 to 207,670; pumps from 8,373 to 52,794. The number of rice threshers has not increased, but a large percentage of them are now power threshers. In 1970 there were 447 grain dryers and 158 grain threshers. Rice transplanters and combines have been experimented with for several years and began to be extended last year.

During past years, effort in farm mechanization has been concentrated on extending power tillers and mechanizing rice culture. So far, farm mechanization has been limited to the use of a few kinds of machines. Only the operations of land preparation, pest and disease control, and irrigation are partially mechanized.

The application of planting, cultivating and harvesting machines as well as the use of herbicides are still in the stage of experiment and demonstration. There is still a long distance to go before the goal of full mechanization in agriculture is achieved. In crop production, harvesting and planting require a large amount of labor; until harvesting and planting machines become common, it will be very difficult to move more labor out of agriculture.

Problems faced in mechanization

In promoting farm mechanization, we have faced a number of difficult problems. The progress of farm mechanization will largely depend upon our effort to solve these problems.

1. HIGH PRICE OF FARM MACHINERY AND LOW PURCHASING POWER OF FARMERS

The price of farm machinery is a key factor affecting its extension and utilization. It will be very difficult to use farm machines if their prices are beyond the financial capacity of

Table 3. Comparison of Farm Machinery Prices in Taiwan and Japan.

Machine	Brand	Price in Taiwan: Type	Price in Taiwan: Engine or horse power	Price in Taiwan: Retail price (NT$)	Price in Japan: Type	Price in Japan: Engine or horse power	Price in Japan: Retail price (NT$)	Price ratio between Taiwan and Japan (percent)
Power tiller	Kubota	KMB 220	VC	59,500	KME 231	ER 100–1	44,670	133.19
	Kubota	KR 850	ES 8	43,000	KR 850	ER 80–1	32,220	133.45
	Kubota	T 650	ER 5	33,500	T 65 (H)	ER 50–2	23,480	142.67
	Isaki	KFG 601	NT 95k	54,000	KFH KL	F 9	38,780	139.22
	Isaki	KLT	F 10Y	59,500	1100W 54	F 10C	44,330	134.22
	Isaki	CT 57M	F 6	42,000	K 48C	F 6	28,780	145.93
	Mitsubishi	CT 95	SD 10	59,500	CT 95 (2.4)	SD	41,780	142.41
	Mitsubishi	CT 95	SD 8	55,000	CT 95	SD 8C	38,110	144.32
Engine	Kubota	VC	10–13 HP	29,000	ER100–1	10–13 HP	16,780	172.58
	Kubota	KNDR 5	6–8 HP	17,500	ER 65–2	6.5–8 HP	10,670	164.01
	Yanmar	F 10Y	10–13 HP	25,000	F 10	10–12 HP	16,670	150.00
	Yanmar	F 6Y	6–7.5 HP	14,500	E 6	6–7 HP	9,890	146.61
	Yanmar	F 4Y	4–5 HP	11,000	F 4	4–4.5 HP	7,000	157.14
	Mitsubishi	SD 10	10–14 HP	28,000	SD 10H	10–14 HP	17,890	156.51
	Mitsubishi	SD 5	5–7 HP	14,400	SD 5H	5–7 HP	8,890	161.97
	Mitsubishi	SD 4H	3.5–4.5 HP	9,500	SD 4H	3.5–4.5 HP	6,890	137.88
Power sprayer	Yanmar	MKR 10	37 cc.	6,500	MKR 10A	37 cc.	3,890	167.10
	Kubota	ADM 10	37 cc.	5,500	ADM 30	37 cc.	3,644	150.93
	Sikutari	DMG 40	35 cc.	5,500	DM 40A	35 cc.	3,567	154.19
	Sikutari	DMG 31	50 cc.	6,000	DM 50	50 cc.	3,900	153.85
	Minoru	DK 52	52 cc.	5,500		52 cc.	3,556	154.67

Source: Zyuro Kudo, *A Study of the Problems of Farm Mechanization in Taiwan*, JCRR, 1970, p. 21.

the farmers.

The prices of farm machinery in Taiwan are about 40 percent higher than in Japan, as shown in Table 3.

The high prices of locally made farm machinery may be attributed to high interest burden, shortage of well qualified technicians, poor management of manufacturers, and the small size of the domestic market.

For imported farm machinery and parts, the current rate of customs duty and surtax is equal to 15 percent of the import price.

Besides, the interest burden of buying farm machinery and the fuel prices are also relatively high. On the other hand, the purchasing power of farmers is rather low. According to the farm income survey, the average farm income was NT$40,388 in 1967, and the farm surplus averaged only NT$3,219.[6] Under such circumstances, it will be very difficult to promote farm mechanization without government support.

2. SMALL FARM SIZE AND FRAGMENTATION OF LAND

The average farm size in Taiwan is only 1.03 hectares, and about two thirds of farms are below one hectare. The land of a farm is seldom concentrated in one tract; it has been estimated that more than half of the farms have at least three plots of land each and that about 75 percent of farm lands are not on farm roads.[7]

Such a situation certainly influences the efficiency of using farm machinery. However, the obstacles may be removed through implementation of land consolidation and encouragement of joint operations.

3. LACK OF FARM MACHINES SUITABLE FOR LOCAL CONDITIONS

Though a great variety of farm machines may be introduced from other countries, they are not necessarily applicable to local conditions. Because of differences in climate, topography, farm size, crop patterns and farmers' customary practices, modifications have to be made in the imported machines.

For example, the Japanese-type small rice combine has not functioned well during demonstration, especially its cleaning device, which does not perform properly when the moisture content of the grain is too high in early morning or after a rainfall. Furthermore, some paddy fields in Taiwan are too soft at harvesting time to support the heavy machine, and grain loss is higher in harvesting by rice combine.[8]

The grain loss is much higher still in using a binder. To fully utilize these machines will require a new variety of rice and improvement of the machines.

The farm machines in use at present are mainly for land preparation, pest control, and water pumping. There is a great lack of machines for other farm operations such as seeding, transplanting, fertilizer application, cultivation, and harvesting of various crops.

4. DIVERSIFIED FARM ENTERPRISE

The farm enterprises in Taiwan have been highly diversified in order to utilize farm labor fully and to maximize the productivity of land. Since the farm machinery and implements needed for one crop may differ from those for others, a diversified farm has to purchase more farm machines.

Diversification of farm enterprises within a region also increases the difficulty of farmers' using machines jointly. Under the diversified, intensive cropping system, the practice of relay-interplanting is followed in many areas, which is also unfavorable for using farm machines.

5. BACKWARDNESS IN TECHNIQUES OF FARM MACHINERY

As has been mentioned earlier, agricultural technical innovation has been focused on biological aspects, and mechanical improvement has lagged behind. Performance in improving existing farm machines and in developing new ones has been far from satisfactory because investment in research, experimentation, and training has been insufficient and both the government agencies and farm machinery firms have lacked qualified technicians and research facilities.

Due to backwardness in techniques as well as lack of an effective quality control and inspection system, the quality of locally produced farm machinery is relatively poor, which may either reduce the efficiency or increase the cost of using machines.

6. INSUFFICIENT REPAIR AND MAINTENANCE SERVICES

The repair and maintenance services of manufacturing firms affect not only the efficiency of machines but also the confidence of farmers in using them.

In earlier years there were more than thirty brands of power tillers in Taiwan, each with only a small share of the market. Owners were spread over the whole island, and maintenance service for the tillers of most manufacturers was totally lacking.

Owing to the short time interval between crops and the tight farming schedule, farmers suffer from delay of operations once a machine is out of order and cannot be repaired quickly. Farmers therefore may hesitate to use machines.

At present there are only a few farm machinery manufacturers whose after-service has been strengthened, and even their selling agents are stationed only at principal townships. Some farmers still complain about inconvenience of maintenance and repair services. As regards imported machines, changes in model or design are relatively frequent, which tends to aggravate the difficulty of repair and maintenance due to lack of spare parts.

7. LACK OF SKILL AND KNOWLEDGE IN USING MACHINES

Most farmers are not very skillful in operation and maintenance of farm machines, particularly the newly developed or newly introduced machines. This leads to inefficient use of machines, and sometimes to damage of them.

To overcome these handicaps, an extensive education and training program should be undertaken by the government to teach agricultural extension workers as well as farmers about farm machinery.

Policy Measures for Promoting Farm Mechanization

The government has played an important role in promotion of farm mechanization. The major government actions include provision of loans and subsidies, establishment of agricultural machinery promotion centers, organizing of agricultural machinery teams, implementation of land consolidation, and conduct of research and experimentation. A Four-Year Farm Mechanization Plan has been inaugurated.

Loan for purchasing farm machinery

Farmers may obtain agricultural machinery loans from the Taiwan Provincial Food Bureau (PFB), the Land Bank of Taiwan, and the Cooperative Bank of Taiwan. The total amount of loans for procurement of farm machinery and implements from 1958 to 1970 is estimated at more than NT$1,500 million (Table 4), of which about 75 percent was used for purchasing power tillers.

The loans of PFB are to be paid in kind with monthly interest rates of 0.75 percent for power tillers and 0.84 percent for other machines. The interest rate for loans of other credit agencies is 0.96 percent per month. Agricultural machinery loans are mostly repaid in semi-annual installments. The credit terms range from a few months to a maximum of seven years. Since both capital returns in agriculture and farm income are

Table 4. Agricultural Machinery Loans, 1958–70.

Unit: NT$1,000

Year	Land Bank of Taiwan	Cooperative Bank of Taiwan	Provincial Food Bureau	Farmers' Association Credit Departments	Total
1958	9,135	792	2,660	—	12,587
1959	26,841	4,386	24,156	—	55,383
1960	32,682	623	47,345	—	80,650
1961	7,387	475	52,985	11,228	72,075
1962	28,663	3,532	64,153	27,372	123,720
1963	27,054	21,846	4,904	57,398	111,202
1964	36,460	21,783	10,529	56,395	125,167
1965	37,291	25,011	8,512	66,908	137,722
1966	52,245	30,574	12,061	62,675	157,555
1967	67,897	32,035	7,960	57,765	165,657
1968	99,576	44,785	14,791	54,844	213,996
1969	81,478	37,388	65,405	64,493	248,764
1970		13,936	56,089	57,587	

Source: JCRR, Land Bank of Taiwan, Cooperative Bank of Taiwan, and Provincial Food Bureau.

relatively low, the prevailing interest rate is considered too high.

Provision of subsidies to farmers

Since the purchasing power of farmers is low, government subsidies will be very helpful to them in acquiring farm machinery and implements. In 1958 the Provincial Food Bureau began to subsidize those farmers who borrowed from it to purchase power tillers and power sprayers or dusters. The subsidy for a power tiller was NT$1,000 to NT$3,000, depending on the horsepower, and the subsidy for a power sprayer was NT$500. Farmers have not been very interest in these subsidies, because the interest rate of the loans provided by PFB is about the same as the ordinary interest rate of commercial banks, and it is often inconvenient to farmers to repay loans in kind.

Since fiscal year 1970, both PFB and JCRR have provided subsidies for purchasing newly extended farm machinery and locally made machines. However, due to limitation of funds, the amounts of subsidy for each kind of machinery are

Table 5. Standard Subsidies for Purchasing Agricultural Machinery.

Unit: NT$/machine

	PFB	PDAF
Tractor	30,000	–
Power transplanter	5,000	5,000
Binder	10,000	–
Power grass cutter	1,000	–
Combine	20,000	37,800
Hand push transplanter	–	2,150
Dryer	–	4,250
Power tiller	5,000	–
Power sprayer or duster	500	–
Power rice thresher	500	–
Cultivator	1,500	–

Source: Provincial Department of Agriculture and Forestry and Provincial Food Bureau.

restricted. Table 5 shows the kinds and amounts of agricultural machinery subsidies.

Township agricultural mechanization promotion centres

Under the financial support of the Provincial Department of Agriculture and Forestry (PDAF) and JCRR, 24 township agricultural mechanization promotion centres have been set up since 1968. They are operated by township farmers' associations under the guidance of JCRR, PDAF, district agricultural improvement stations, and the prefectural government.

The functions of the township agricultural mechanization promotion centres are: (1) to teach farmers the skills of using farm machinery, (2) to demonstrate mechanized farming operations, (3) to extend farm machinery and implements and help farmers apply for loans and subsidies, (4) to provide repair and maintenance services for farmers, (5) to organize farmers' machinery custom service teams and assist member farmers in seeking custom work.

Most of the township agricultural mechanization promotion centres have been successful in operation, and farmers are satisfied with their services. The progress of farm mechanization in areas with agricultural mechanization promotion centres is faster than in areas without them.

In 1970 the 24 townships with promotion centres owned about 4,500 power tillers, or 16 percent of the total number of power tillers in Taiwan, while their cultivated land area constituted only 7 percent of the total. The agricultural mechanization promotion centres not only help farmers, but also lessen the after-service burden of agricultural machinery manufacturers.

Assisting farmers' associations to establish machinery teams

In fiscal year 1970 the PFB began to assist township farmers' associations in establishing agricultural machinery teams. The purpose of the agricultural machinery teams is to serve the farmers in land preparation, pest control, and harvesting, so as to mitigate labor shortage problems and lower the rates charged for custom work.

By the end of May 1971 a total of 103 teams had been established in 59 townships, with 1,479 farmer participants.

Table 6. Farmers' Association Agricultural Machinery Teams, May 31, 1971.

Food district	No. of FAs with machinery teams	No. of machinery teams	No. of member farmers participating	No. of farm machines				
				Power tillers	Tractors	Power sprayers	Power threshers	Binders
Taipei	4	8	70	38	—	9	8	—
Shinchu	8	26	422	146	—	19	66	—
Taichung	10	17	290	71	—	49	34	4
Tainan	19	34	368	166	4	16	4	—
Kaohsiung	18	18	329	18	12	82	13	—
Total	59	103	1,479	439	16	175	125	4

Source: Taiwan Provincial Food Bureau

These agricultural machinery teams were equipped with power tillers, tractors, power sprayers, power threshers, and binders. Detailed figures are shown in Table 6.

According to the plan of PFB, 300 agricultural machinery teams will be established in rural areas within four years. On the average, the PFB has provided subsidies of NT$65,150 and low-interest loans of NT$398,600 team.

The writer has investigated some of the agricultural machinery teams and has found that these teams may fail to perform the functions originally expected for the following reasons: (1) lack of technicians and full-time machine operators; (2) the small difference between the rates charged by the agricultural machinery teams and by farmers doing custom work; (3) the limitation in kinds and numbers of farm machines due to shortage of funds; (4) the practice in some townships that the farm machinery is actually bought and operated by private farmers; (5) low operating efficiency of the agricultural machinery teams.

Implementation of land consolidation program

Land consolidation may be considered as a coordinated step for promotion of farm mechanization. The purpose of land consolidation is mainly to enlarge plot size, to improve the shape of land plots, and to rearrange farm roads and irrigation and drainage systems so as to facilitate mechanized farming.

A total of 280,000 hectares of farm land have been consolidated since 1959. Another 200,000 hectares will be consolidated in the coming ten years. Land consolidation has greatly improved farm layout, and the number of power tillers in use has increased significantly. [9]

Investment in research, experimentation, and training

Research, experimentation, and training are indispensable for extension of farm machinery. Many organizations carry on such work—National Taiwan University, Taiwan Provincial Chung Hsing University, Taiwan Provincial Institute of Agriculture, agricultural research institutes, district agricultural improvement stations, farmers' associations, and the Taiwan Sugar Corporation.

The Government has appropriated funds for the organizations to undertake such work. However, the funds appropriated were very limited before the promulgation of the Four-year Farm Mechanization Plan in 1970.

Four-year Farm Mechanization Plan

In view of the urgent need for farm mechanization in Taiwan, a Four-year Farm Mechanization Plan was inaugurated in fiscal year 1971.[10] Within the four year period it is planned to extend 120,400 farm machines and implements of various types, such as power tillers, sprayers, threshers, combines, sprinkler sets, rice transplanters, grain dryers, grass cutters and cultivators. (Details are given in the paper by Y.T. Wang, Table 4, page 224.)

Power tillers are the most important. The goals for power tillers to be extended are 6,000 for the first year, 8,000 for the second year, 11,000 for the third year, and 15,000 for the fourth year. It is expected that land preparation and pest control on about 450,000 hectares of cultivated land will be mechanized, while mechanized transplanting, cultivating and harvesting operations will be carried out on a large part of the area.

The costs for implementing the Four-year Farm Mechanization Plan total NT$2,265 millions, of which NT$103 million will be appropriated in the form of grants for promotion expenses, and NT$2,162 millions in the form of loans for procurement of farm machinery.

In order to facilitate the implementation of the farm mechanization program, a Farm Mechanization Promotion Committee (FMPC) has been set up under the Ministry of Economic Affairs. The FMPC consists of representatives from JCRR, the Council for International Cooperation and Economic Development, PDAF, and PFB. It serves to advise, supervise and coordinate the execution of farm mechanization programs.

Under the plan, a number of measures are to be adopted for promoting farm mechanization. The following are the most important:

1. *To improve the quality and reduce the price of agricultural machinery.*

Though the prices of power tillers and other farm machinery have been reduced slightly, they are still much higher than the prices in Japan (see Table 3). The government is making plans to improve the quality and to lower prices of farm machines by (1) providing low interest loans to well qualified manufacturers; (2) strengthening the inspection of farm machinery and the standardization of machinery parts; (3) giving exemption from import duty on farm machinery and spare parts which are not manufactured locally.

2. *To provide loans and subsidies to the farmers.*

It is planned that more government subsidies and long-term low-interest loans will be made available to farmers for acquisition of farm machinery. In the four-year period, loans for purchasing farm machines will total NT$1.5 billions and subsidies will amount to NT$36 millions. Through financial assistance, the farmers will be given opportunities to gain experience in handling newly introduced or newly developed farm machinery for general adoption.

3. *To set up more township farm mechanization promotion centres.*

According to the four-year plan, the number of township farm mechanization promotion centres will be doubled by the end of 1974. The efficiency of the centres will be promoted by recruiting more qualified technicians and providing sufficient facilities for servicing different kinds of farm machines. Meanwhile, efforts are to be made to fully utilize the existing machines, to extend new machines, and to train more farmers in use of farm machinery.

4. *To strengthen experimentation, research and training.*

Experimental and research work will be stepped up through recruitment of more well-qualified research workers and expansion of facilities in agricultural colleges, agricultural research institutes, and district agricultural improvement stations. It is planned to send technicians and research workers abroad or to local universities for advanced study or short-course training. In addition, an agricultural mechanization research institute will be established. Its primary function will be to conduct fundamental research on agricultural machinery and to train technicians.

5. *To initiate a pilot project for promotion of modernized agriculture.*

A multi-phase experiment in farm modernization will be undertaken in selected areas. The experiment will emphasize the use of relatively large farm machinery, modernization of farming techniques, practices in supplying farm inputs, marketing and processing of farm products, and farmers' organization. Several experimental areas will be selected to test the feasibility of mechanized farming on a joint basis in different agricultural regions. A cooperative farming unit with 100 hectares of paddy field in one tract has already been established in Huatan, Changhua Prefecture. All farming operations are mechanized. The farmers are organized into ten teams, each treated as an operating unit, with production costs and produce shared by the members according to their areas of land. Another experimental area for upland crops will soon be established in Hsin-Kang, Chiayi Prefecture.

6. *Other coordinated steps for farm mechanization.*

In order to assure efficiency, the extension of farm machinery and implements is to be carried out in close coordination with land consolidation, irrigation and drainage, integrated demonstration of improved cultivation techniques, and joint farming operations.

Some Policy Considerations

Need for coordination in promotion of farm mechanization

Closer coordination is urgently needed for promoting farm mechanization in Taiwan.

Firstly, farm mechanization policy is an integral part of agricultural and economic policy, and the target of farm mechanization must be embodied in and be in conformity with the economic development plan. To keep pace with the demand for over-all economic development, a long-run farm mechanization plan should be mapped out based on the long-term Economic Development Plan.

Secondly, at present the organizations involved in carrying out farm mechanization programs are not well coordinated. The research and experiment programs conducted by universities, agricultural research institutes, and the district agricultural improvement stations should not overlap, and the PDAF and PFB should have better cooperation with one another. To improve coordination, the functions of the Farm Mechanization Promotion Committee have to be strengthened.

Thirdly, intimate cooperation among engineers, agronomists, economists and sociologists is also required, as team work is usually more effective.

Strategies for extension and utilization of farm machines

There are different strategies for extension and utilization of farm machines, and it is of vital importance to find out which are most suitable in different situations. The main alternatives are as follows:

(1) *Self-purchase for self-use*. This is the best way for those countries with large farms. The United States, Canada and Australia are good example. In Taiwan, small machines may be purchased by individual farmers for their own use. For large machines, systems of custom service or cooperative utilization have to be set up.

(2) *Joint purchase and joint use*. In countries with small-farm agricultural systems, one often finds a few farmers purchasing and using farm machines jointly. This method has been undertaken in Taiwan but has not been very satisfactory, owing to the technical difficulties in making arrangements for using machines. It seems more advisable for one farmer to purchase and operate the machines but to perform machine work for other farmers on a joint basis.

(3) *Farm machinery cooperatives*. Machinery cooperatives are rather popular in Western Europe. Whether they are adaptable to Taiwan is unknown, and trial of establishing such cooperatives is needed.

(4) *Farm machinery teams of farmers' associations*. In Japan, custom service rendered by farmers' associations is expanding rapidly.[11] In Taiwan, many township farmers' associations have farm machinery teams, but they are not very effective because of the shortcomings mentioned earlier.

To make these teams perform their functions properly, it is suggested that the number of teams should not increase too fast, that they should be established in the areas where the financial status of township associations is sound, and that additional financial support from the government should be given to improve facilities.

(5) *Farm machinery custom service companies.* This system is popular in West Germany, Holland, and Sweden. No farm machinery custom service company has been created in Taiwan. However, most power tiller owners provide custom service for other farms. A survey by PDAF showed that more than 52 percent of power tiller working hours are spent in custom work.[12]

In order to extend the utilization of large-type machines, it is practicable to encourage the establishment of farm machinery custom service companies.

Types of machines to be developed.

Farm mechanization is not confined to rice culture, and equal attention should be paid to other crops and to animal industry. Unless all operations in crop production are mechanized, it is unlikely that much labor can be released from agriculture, even if a considerable amount of labor can be saved. Therefore, the extension of machines for the operations of planting, cultivating, and harvesting is especially important.

There has been controversy regarding the question of whether small-type or large-type machines should be developed. Some have argued that the tractor era must be inaugurated and the tiller era ended immediately if farm mechanization is to be expedited.[13] Some others think that power tillers are more suitable for the small farms of Taiwan.

The operation cost of large machines per unit of land is usually lower than of small ones. Of course, in extension of large machines the cost for organizing farmers should be taken into consideration.

In the meantime, under certain circumstances, the small machine may be even more economical. It may be more appropriate to adopt an evolutional rather than a revolutional process in developing farm machines, so that small machines and large machines can be utilized side by side.

Expansion of farm size and specialization of farm enterprises

In the long run, farm size should be expanded in order that farm machinery can be more effectively used. Several steps can be adopted, such as: (1) guiding farmers to leave farms through occupational training, (2) providing long-term low-interest loans for farmers to purchase land, (3) modifying the existing land law and regulations.

Because of the high man-land ratio in Taiwan, it is practically impossible in the foreseeable future to expand the average farm size enough so that farm machines can be effectively used within individual farms; therefore some form of joint operations is needed.

Specialization of farm enterprise and simplification of farming operations are also helpful in using farm machines. Where a great number of farms of the same type comprise a specialized farming region, e.g., a banana region, vegetable region, dairy farm region, or fruit region, it is much easier to organize the farmers to use farm machines or to perform other farming activities on a joint basis.[14]

Conditions of loans and subsidies.

The amount of credit for purchasing farm machines seems adequate, but the interest rate is too high, and the security requirements are too rigid. It is suggested that farm credit for improving the basic structure of agriculture, i.e. farm machinery loans, be distinguished from ordinary farm credits and be provided at a lower interest rate.

Most farm machinery credit is in the form of real estate mortgage loans. It would seem helpful to allow farmers to borrow money against movable property.

Subsidies provide a stimulus for expansion of farm machines, especially in the early stage of extension. Since the funds of the government are so limited, subsidies should be restricted to newly developed machines. However, the number of machines to be subsidized should not be restricted, and standards of subsidy for the same kind of machines should be unified.

Guidance of farm machinery industry

The farm machinery industry has great influence on the promotion of farm mechanization. Because of the backwardness of the farm machinery industry in Taiwan, the prices of farm machines are high and the quality is low. Meanwhile, the local manufacturers provide only power tillers and some other simple machinery and implements, and all newly developed machines are imported from foreign countries.

Problems relevant to policy towards the farm machinery industry include: (1) whether farm machines should be imported or made locally, (2) whether the number and scale of farm machinery firms should be restricted, (3) how to assist existing manufacturers to reduce production cost, improve quality, and develop new machines adapted to local conditions. These problems need further investigation.

Summary

Since the implementation of the successive four-year economic development plans began in 1953, agricultural development in Taiwan has shown remarkable progress and contributed greatly to economic development. However, due to changes in economic structure and the large absorption of rural labor by industry in recent years, the pattern of agricultural development has undergone considerable adjustment.

Capital-intensive production methods centering on farm mechanization will be the main direction of agricultural development in the future. Promotion of farm mechanization may solve the farm labor shortage problem and improve farm labor productivity. It is also the only way to release more labor for the use of industry and other economic sectors in the years to come.

Despite the fact that farm mechanization has been going on in Taiwan for more than twenty years, its progress has not been very remarkable. Up to the present, farm machines are used mainly for land preparation, pest control, pumping irrigation water, and transportation. Machines for planting, cultivating, and harvesting are still under experimentation and demonstration. There are many technical, economic, and institutional problems facing farm mechanization. These problems can be solved with the positive support of the government.

The essential measures are to lower the prices and improve the quality of agricultural machinery, to provide more loans and subsidies to farmers, to assist manufacturers, to establish more agricultural mechanization promotion centres, and to

strengthen research, experimentation and training.

There remain some policy issues which need further investigation, such as types of machines, patterns of farming, conditions of subsidies and loans, strategies for extension and utilization of farm machines, and problems of coordinating measures for implementation of farm mechanization. These problems must be resolved as soon as possible, and it is hoped that the experiences of other countries may be helpful in developing our farm mechanization policies.

[1] Computed from information in F.H. Tyner and L.G. Tweeten, "Optimum Resource Allocation in U.S. Agriculture," *Amer. J. of Agr. Econ.*, 48(3; pt. 1), Aug. 1966, Table 2.

[2] For a thorough study on this subject see T.H. Lee, "Process and Pattern of Growth in Agricultural Production of Taiwan", *Economy Essays*, Vol. 1, the Graduate Institute of Economics, National Taiwan University, Taipei, Nov. 1970.

[3] Hsieh, S.C., and T.H. Lee, *The Effect of Population Pressure and Seasonal Labor Surplus on the Pattern and Intensity of Agriculture in Taiwan*, JCRR (mimeo.), p. 1.

[4] Oshima, H.T., and W.H. Lai, "Experience of Labor Absorption in Postwar Taiwan", a paper presented at the Conference on Manpower Problems in East and Southeast Asia, Singapore, 22–28 May 1971, Appendix Table 4.

[5] Hsu, Wan-chun, "The Promotion of Farm Mechanization in Taiwan", *Industry of Free China*, 35(5), May 1969.

[6] Rural Economics Division, JCRR, *Taiwan Farm Income Survey of 1967*, Econ. Digest Ser. No. 20, Jan. 1970.

[7] Taiwan Provincial Land Bureau, *General Report on the Demonstration of Land Consolidation in 1961 (FY)*, p. 6.

[8] Peng, Tien-song, "Present Problems and the Future of Agricultural Mechanization in Taiwan," *Industry of Free China*, 34(4) April 1971, p. 17.

[9] Lin, Chin-Tsao, *An Economic Study on Land Consolidation and Agricultural Mechanization*, Dept. of Agr. Econ., Provincial Chung-hsing University, 1965. (In Chinese).

[10] Ministry of Economic Affairs, JCRR, and Taiwan Provincial Government, *The Four-year Farm Mechanization Plan*, March 1970.

[11] Kudo, Zyuro, *A Study of the Problems of Farm Mechanization in Taiwan*, JCRR, Sept. 1970, p. 37.

[12] PDAF, *Report on the Survey of Power Tiller Utilization in Taiwan*, March 1966, Tables 4, 5.

[13] Loh, C.S., "Mechanization of Agricultural Production in Taiwan", *Industry of Free China*, 34(1), July 1970, p. 40.

[14] Wang, Y.T., "The Current Development of Taiwan Agriculture", *Theses on Agricultural Development Problems of Taiwan*, JCRR, April 1971, p. 55.

IMPLICATIONS OF FARM MANAGEMENT RESEARCH FOR GOVERNMENT MECHANIZATION PROGRAMS

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In general, farm machinery is a historical indicator showing the level of agricultural productivity in any country of the world. Bainer, Kepner, and Narger[1] describe the process of mechanization as dynamic, with no ultimate goal in sight. T.H. Lee[2] has emphasized the necessity of farm mechanization in Taiwan. To raise the level of agricultural productivity, farm mechanization is one of the most important policies, especially in the developing countries, even if the size of farm is very small.

Progress of Farm Mechanization in Japan

In Japan, some increased production in the past must be credited to advances in non-engineering phases of agricultural technology such as better crop varieties, the more effective use of fertilizer, and improved cultural practices. Since the Land Reform, however, a major factor has been the increased utilization of non-human or non-animal energy and of more effective machines and implements. This application of machines to agricultural production has been one of the outstanding developments in Japanese agriculture during the past 15 years.

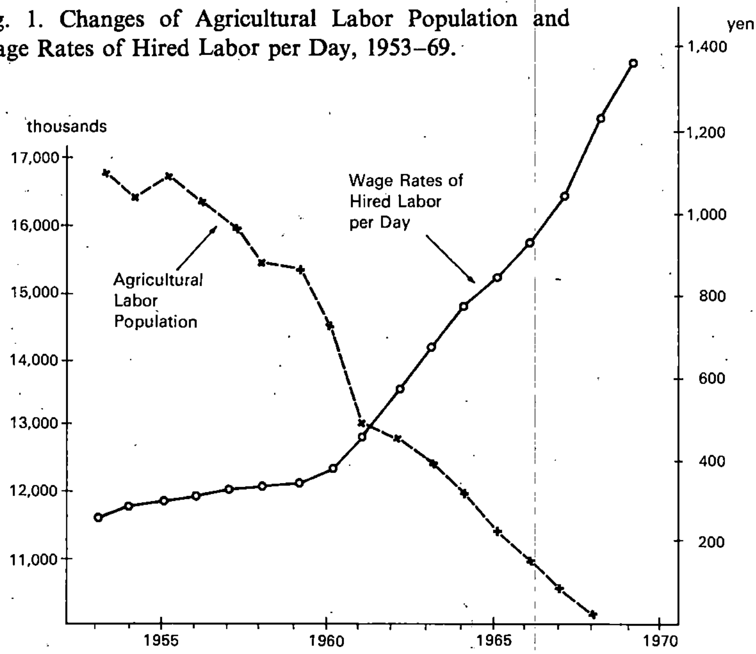
A great number of agricultural machines were introduced on farms in the 1960s. The power tiller, especially, marked a turning point in Japanese agriculture.[3] The number of power tillers was about 3.1 million in 1970 as compared with only 35,000 in 1953. In contrast, the number of draft cattle and horses decreased from 3.6 million to 1.9 million during the same period.

About 40 percent of farmers had no power tiller in 1970, but most of them used the power tiller for plowing of paddy fields through custom work. As a result, it is difficult to find horse plowing and cultivating in the rural area at the present time. Therefore, we say that the stage of Japanese agriculture has already developed from the horse economy to the power-tiller economy.

Gradually, but continuously, most farmers have introduced several kinds of small machines such as power sprayer, power thresher, power dryer, truck, and so on. This advance in farm mechanization has been caused by a strong demand for labor in other industries that has withdrawn workers from the land and forced wage rates up. Severe labor shortages and high wage rates in the rural areas since 1960, together with the simultaneous demands for increased agricultural production, have had a marked influence on the mechanization of various operations.

As shown in Figure 1, the agricultural labor population has decreased from about 17 million in 1955 to 10 million in 1969,

Fig. 1. Changes of Agricultural Labor Population and Wage Rates of Hired Labor per Day, 1953–69.



Source: K. Tsuchiya, "The Role and Significance of Mechanization in Japanese Agriculture," *Faculty of Agriculture, Kyushu Univ.,* 16 (2), 1970.

and the wage rates of agricultural hired labor have increased from about 400 yen per day in 1960 to 1,370 yen in 1969.

Many results of farm mechanization are evident. It has released a great number of agricultural workers to other industries, thus contributing to the remarkable industrial expansion in Japan and to the high standard of living that now prevails in this country. The burden and drudgery of farm work has been greatly reduced, and the output per farm worker has been greatly increased.

But it has not been effective for cutting down the production cost of agricultural products. For instance, rice is a main crop that has been most mechanized in Japan. It could be produced with about 1,281 man hours of labor per hectare in 1969, compared with 1,908 man hours in 1953, as shown in Table 1. In spite of this saving of labor with relatively high farm wages, the production cost has increased from 5,601 yen per 150 kg. of brown rice in 1953 to 12,587 yen in 1969, because of the rise of price of production materials.

Especially, both the depreciation cost of machines and its ratio to the total production cost have sharply increased. Therefore, a very important problem for farmers and farm management researchers is how to use machines economically on small-scale family farms.

Moreover, the Japanese Government has changed its price adjustment for the surplus rice produced, and emphasized promotion of more mechanization and land improvement under the Second Project of Agricultural Structure Improvement last year. On account of these changes of social-economic conditions, farm management research will be increasingly important for farm mechanization in Japan.

This report first describes Japanese Government measures for promoting and supporting farm mechanization, especially the role of policy under changing social-economic conditions, as reported by the Farm Mechanization Committee to the Ministry of Agriculture and Forestry in 1970. It then tells the story of the development since 1960 of farm management research relating to mechanization, which has been conducted mainly in the National and Prefectural Agricultural Experiment Stations.

Table 1. Production Cost of Brown Rice per 150 kg.

Year	No. of farm households tabulated	Production cost			Yield per hectare	Labor hours per hectare
		Total	Depreciation of machines			
		(yen)	(yen)	(percent)	(kg)	(hours)
1953	2,980	5,601	291	5.2	3,090	1,908
1954	2,999	5,756	324	5.6	3,230	1,858
1955	3,000	4,773	289	6.1	4,140	1,918
1956	2,813	5,215	342	6.6	3,900	1,833
1957	2,834	5,187	373	7.2	3,980	1,773
1958	2,859	5,206	409	7.9	4,150	1,815
1959	2,852	5,019	429	8.5	4,310	1,757
1960	5,044	5,218	482	9.2	4,440	1,715
1961	4,867	5,946	691	11.6	4,360	1,657
1962	5,051	6,345	774	12.2	4,460	1,520
1963	4,995	7,121	911	12.8	4,420	1,451
1964	4,869	8,126	1,127	13.9	4,460	1,472
1965	4,741	8,804	1,228	13.9	4,450	1,410
1966	4,913	9,491	1,352	14.2	4,550	1,400
1967	5,031	9,770	1,441	14.7	5,020	1,394
1968	5,065	10,883	1,711	15.8	4,970	1,327
1969	4,062	12,587	2,256	17.9	4,840	1,281

Source: Survey of Production Cost of Rice, Statistics and Survey Division, Ministry of Agriculture and Forestry

Role of Government Farm Mechanization Policies

The outstanding advance in farm mechanization was due mainly to a shortage of agricultural labor, a rapidly expanding and effective development of farm machinery industries, and effective government policies for promoting and supporting farm mechanization.

In 1961 the Agricultural Basic Law was established, which emphasized promotion of farm mechanization for increasing agricultural productivity. Under this law, until about 1965, the Government gave financial support and long-term loans for introducing new types of machines to farmers, because machinery was expensive for farmers compared with other materials or agricultural products, and few farmers had enough money to buy new machines such as power tillers, power sprayers, and power dryers.

The rate of subsidy was usually about 5 to 10 percent of initial cost in the case of power tillers.

The subsidy played an important role in their introduction into Japanese agriculture, as a pump-priming policy in the early stage of farm mechanization. The new machines introduced had a great demonstration effect on neighbors in the areas. As ownership of a particular machine such as a power tiller became widespread among farmers, the subsidy system was cut off, usually after 2 or 3 years, because it had almost finished its function.

Because the organization of credit to enable farmers to buy machinery was not well developed, the Government in 1961 reestablished the Agricultural Modernization Fund, which was a kind of mechanization loan. A farmer who wants to utilize this loan for introducing any new machine can borrow up to 2 million yen for 7 years with only 5.5 percent interest.

The amount of such loans has increased year by year. In the early stage of farm mechanization, most farmers were afraid of any loan, because of their low repayment ability. Recently, their attitude toward loans has been changing, especially on the large-size farms.[4]

Also, since 1956 farmers have been exempt from tax on gasoline used in machines on their farms. (Ordinarily, the Government uses the gasoline tax funds for highway improvement, but farm machines do not use the roads.) At present, the market price of light oil is about 38 yen per litre, but farmers can buy it at 23 yen without tax for farm work. On heavy oil and kerosene they pay the same tax included in the market price to other consumers.

Furthermore, farmers benefit indirectly from the gasoline tax through the special rural road investment funds. These funds are used specifically for building roads for transportation of agricultural products. Road construction is the responsibility of the Ministry of Building and Construction, but there was not enough construction in the rural areas. Therefore, this collateral fund from the gasoline tax has also been of great benefit to farmers and farm mechanization.

A Farm Mechanization Training Center was built by the Government in Ibaragi Prefecture in 1960. Most Agricultural Co-operative Associations have set up service stations for repair of machines in rural areas. Sometimes combined exhibitions of new machines and machinery training schools are provided for farmers by the associations and manufacturers.

These many measures have combined to bring about the rapid introduction of many different machines in Japanese agriculture within a short time. If the Government had not supported or promoted farm mechanization, its speed of introduction would have been slow and a long time would have been required to reach the present level.

However, a great number of young workers have gone to the cities, so that the shortage of agricultural labor has been increasingly serious, especially since 1965. Part-time farms constituted about 84.4 percent of Japan's 5,342,000 farms in 1970.

Furthermore, an important political problem of surplus rice developed in 1969. The Government has required a decrease of 20 percent in total yield or acreage of rice, and controlled the price so that it went up only a little in 1970. Also, the Government has been requested by foreign countries to permit free trade in agricultural products. Therefore, the Japanese Government has recognized the basic administrative necessity to improve the agricultural structure essentially and to promote farm mechanization more strongly in order to cut down the cost of agricultural products.

In the Second Project of Agricultural Structure Improvement,[5] a subsidy was given to group farming systems for introducing large-size machines such as tractors and attachments, combines, speed sprayers, rice centers, etc. The total amount of subsidy was about 12.0 billion yen for farm mechanization in 1970, compared with 5.3 billion yen in 1968 and 7.7 billion yen in 1969. For this reason, most recent research in the public stations has dealt mainly with the advanced, large machines.

Farm Management Research on Mechanization

In the National or Prefectural Experiment Stations, farm mechanization research projects frequently have been initiated at the request of some influential outside group or administrative organization whose members would directly benefit from the results, or at the suggestion of personnel within the research agency who recognized the importance of the problems. Co-operative projects between agricultural engineers and various agricultural science groups have been common in experiment station work.

In a proposed project, a survey is first taken of use of the machine, especially in the case of power tillers, and an evaluation is made of the potential application of the results and of their value to farmers in terms of labor saving, improved work operation, decreased operating cost, increased farm income, etc.

Since 1965, a new Department of Farm Mechanization or Farm Organization has been established in each National and Prefectural Agricultural Experiment Station, where a number of technical research studies have been begun in order to guide the improvement of machines under different regional conditions. They have included development of new models similar to existing machines, design changes to reduce the manufacturing cost of a machine, comparative testing of several machines, and evaluation of the work performance of particular machines.

Studies related to the more efficient utilization of existing machines have been emphasized, because the field conditions on farms differ from those in the experimental fields. An example is the determination of proper adjustments and operating conditions for a combine in order to minimize grain damage and losses.

In addition, operating costs of new types of machines have been compared with costs using conventional tools or old types of machines. Such studies use field investigations and farm surveys, and are usually conducted by the Department of Farm Management rather than in commercial organizations or universities.

Sometimes the Government has requested the public stations for research results or data which will be useful in carrying out its farm mechanization measures. For instance, special research on rice center organization and management was undertaken systematically by the staffs of the Departments in eight National Experiment Stations under the Research Council of the Ministry in 1965.[6] The National and six Prefectural Stations conducted a three-year co-operative research study on social-economic conditions of tractor farming in the Tohoku Region.[7] This was directly related to the Project of Agricultural Structure Improvement.

The purpose of farm management research is to accumulate scientific information that can be applied elsewhere concerning economics of mechanization on farms. The results of such research are obviously useful to farmers, extension workers, and administrative officers.

Economic evaluation of the power tiller

In the early stage of farm mechanization, most farmers had learned something about the work efficiency and work performance of power tillers. Most researchers in the public stations or universities first made surveys of its practical operation on farms and these studies made clear its technical effects.[8] They may be summarized as follows:

1. *Increasing labor efficiency*. Labor saving is one of the most important effects, and labor efficiency has increased remarkably in each job. For instance, plowing a paddy field with a 7 HP power tiller required 20.0 hours of labor per hectare, compared with 35.0 hours using a draft animal (Table 2). With a 17 HP tractor and rotary tiller the labor used was 8.8 hours, and with a 35 HP tractor drawing two 14-inch plows it was 7.5 hours.

Table 2. Labor Used in Land Preparation and Relative Metabolic Rate Using Different Types of Equipment, Hoshiyama, Iwate Prefecture, 1965.

Type of equipment	Plowing		Harrowing	
	Labor	R.M.R.*	Labor	R.M.R.*
	(hr/ha)	(percent)	(hr/ha)	(percent)
Draft animal with:				
Mould board plow	35.0	6.0	—	—
Comb harrow	—	—	15.5	6.0
7 HP rotary tiller	20.0	3.1	8.8	5.8
17 HP tractor with rotary tiller	8.8	2.5	6.9	
35 HP tractor with:				
Two 14 inch plows	7.5	2.2	—	—
40-inch rotary tiller	8.6	2.0	4.0	
Paddy harrow	—	—	5.7	

Source: Z. Kudo and others, *Economic Study of Use of Co-operative Tractor,* Dept. of Farm Management, Tohoku Natl. Agr. Exp. Sta., Res. Rept., 1965.

* Relative Metabolic Rate shows the degree of fatigue per hour.

In harrowing and leveling, the average number of hours of labor used was only 4.0 hours per hectare with a 35 HP tractor and 40-inch rotary tiller, as compared with 8.8 hours for the power tiller.

On the comparison of labor efficiency of different methods of threshing, hand threshing using a comb-cutter required 2.50 hours of labor per 150 kg. of unhulled rice. The power thresher required 32 minutes; the auto thresher reduced this to only 10 minutes. The efficiency of the auto thresher was about five times that of a treadle thresher.

As a result, farm work can be done quickly, at the right time, and with less labor by machine, and most mechanized farmers have greatly reduced their need for hired labor. Moreover, the labor saved in rice production has been applied to other farm enterprises such as upland field crops or livestock, or to non-agricultural side-work.

2. *Improving work performance*. The performance of a farming operation is a function of three factors: the operating labor, the objects on which the operation is performed (field, crop, etc.), and the farm machine with its working attachments. In other words, the machine stands between labor and object, and these three productive factors are interrelated. Even if a farmer introduces a good tractor on his farm, its work performance is not good under bad field conditions, as when the land is scattered in small strips. Therefore, it is very important to adapt the field conditions, crop variety, cultural practice, and crop system to the new machine and its attachments in order to improve work performance. For example, use of the co-operative power sprayer and new pest control chemicals in group farming has been very helpful in controlling diseases and insects and thus improving the quality of rice.

3. *Simplifying operating work*. Land preparation using draft animals on paddy fields has usually consisted of plowing two times, harrowing two times, and leveling, before transplanting of the rice. By use of power tiller or tractor the number of jobs has been decreased from five to three on the same field. Also, anyone can learn to operate a machine in a short time. Usually, it takes two or three years experience to become proficient in horse plowing, but a farmer can get a tractor driver's license after only about 30 hours training and test at a motor school.

The relative metabolic rates of farm work with machine are definitely smaller than with animal or hand labor. For instance, in plowing with a 35 HP tractor and 40-inch rotary tiller the rate is 2.0 percent per hour, compared to 3.1 percent with a 7 HP power tiller and 6.0 percent with draft animal (Table 2).

On the basis of these three technical effects, the farm system is changed by the use of machines. Not only is there a higher degree of commercial farming, but also there is the opportunity to do custom work with the machine if the owner's farm is not too large. Custom work is plowing or harrowing for other farmers who have no power tiller, and who pay a charge for this service to the owner-operator of the machine. Therefore, custom work helps to increase the annual use of the machine and the profit of the farmer. But this is limited by the operator's available time, the seasonality of farm work, and other factors.

On the other hand, some reseArachers have attempted to compare the operating cost of the power tiller with that of the draft animal and to estimate its economic efficiency of investment. Some different opinions have been reported about the economic evaluation of power tillers on small-scale family farms in Japan.[9]

The "income effect theory" of M. Matuszawa[10] is typical of the opinions opposed to introduction of the power tiller. According to this theory, the return for its introduction has fallen short of its cost and its introduction has resulted in over-investment on farms. Farmers have bought tillers for non-economic reasons, as something similar to consumer goods like washing machines, or as a status symbol.

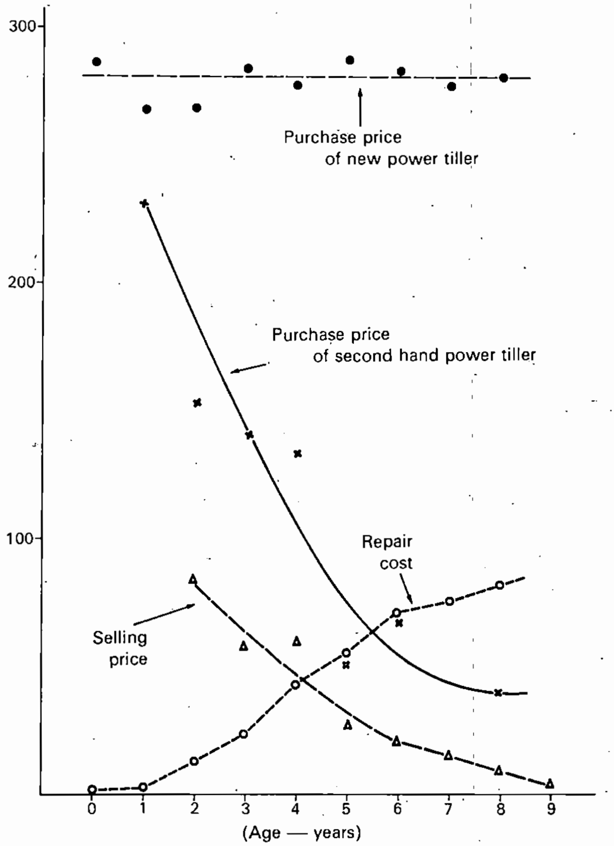
However, fact was stronger than this theory. Tsuchiya has written in his recent report that "the promotion of agricultural mechanization centering around the distribution of power tillers has made Japanese farmers familiar with practical economy. Its extension is only the practical substitution of machinery for human labor—for maximum efficiency to the Japanese farmers".[11]

Umeki made a survey of the effect of the power tiller using farm accounts on 148 medium-sized farms in the Saga Plain Area in 1960. By his report, "comparison between farms with and without power tillers indicated a consistent tendency towards a higher gross farm income, farm expenses, farm family earning, farm capital excluding land, land capital, and farm family labor earnings on farms with power tillers than on comparable sized farms without". Umeki also made clear that the use of power tillers was economical on farms with about one hectare or more of paddy field.[12] At that time, only 17 percent of the total number of power tillers were on farms with less than 1.0 hectare.

Thus, most power tillers have been used economically on Japanese farms. Some researchers have emphasized the need to increase the annual operating hours of a power tiller for cost saving and have made detailed checks of conditions on farms. The annual charges for repairs, maintenance, fuel, and lubricating oil increased in proportion to the age of the power tiller, and economic obsolescence of old tillers also went up sharply because of the outstanding development of farm machinery industries. Therefore, an economic study on the replacement of power tillers was undertaken by the present author which showed that it was most economical on Shonai farms to replace an old tiller with a new one or a medium size tractor every fifth year.[13] (See Figure 2.)

Of course, many researches have been undertaken about other machines such as tractors, harvesters, sprayers, power planters, etc. Of the research subjects in the Departments of

Fig. 2. Average Purchase Price, Selling Price and Repair Cost of Power Tiller by Age (Unit: thousand yen).



Source: Z. Kudo, *Economic Study of the Replacement of Power Tiller on Shonai Farms*, Tohoku Natl. Agr. Exp. Sta. Bull. No. 37, 1969.

Table 3. Operating Cost and Rice Production Cost per Hectare with Different Mechanization Patterns.

(unit: thousand yen)

	Rice producing pattern		
	Power tiller	Medium size tractor	Large size tractor
Total investment in machines	658	3,563	5,067
Size of farm (ha)	2	2 × 5	2 × 10
Operating cost per hectare:			
Fixed cost	78	77	53
Variable cost	13	12	13
Total	91	89	66
Rice production cost per hectare:			
Operating cost	91	89	66
Labor cost	231	111	104
Other	35	73	63
Total	357	273	233
Cost per 150 kg	11.3	8.6	7.4
Yield per hour (kg)	4.12	8.56	9.17

Source: M. Mukai, *Economic Study of the Standard Rice Producing Patterns with Machines,* 1969.

Farm Management in the public stations in 1967, 78 dealt with farm mechanization, about 17 percent of the total.[14] Farm mechanization research has become more active, more extensive, and more practical over the past 15 years.

Experimental research on tractor farming

With the introduction of different machines on a farm, a more useful approach to the study of operating cost is not in terms of a single machine, but rather in terms of all the machines and labor involved. Obviously, these combinations of machines differ from farm to farm. Some of the important combinations are therefore chosen for study as mechanization patterns.

Experimental research has been undertaken by some public stations to establish a new pattern of machines, and to study the mechanization process on farms. Under the leadership of Tohoku National Agricultural Experiment Station, experimental research has been conducted at Bonbana Pilot Farms with a set of large-size machines such as tractors and attachments, which was presented by the Station in 1960. Farmers have increased their dairy production by using these machines for 6 years. The development of their mechanization has been made clear by analysis of farm records kept by the farmers.[15]

Also, pilot farms play an important role in exhibiting farm mechanization effects to other farmers. Therefore, to promote tractor farming the Government set up about 18 pilot farm projects in 1962 and supported them for 3 to 5 years. A similar project is now planned in Taiwan.

At the same time, comparative analysis of operating cost has been made between different mechanization patterns on the basis of experimental and survey data, in connection with the size of group farming. Table 3 shows the operating cost and rice production cost for three typical patterns. Data of this kind are of course very helpful to farmers who are going to introduce new large-size machines co-operatively, and especially for planning Agricultural Structure Improvement Projects.

Conclusion

Farm mechanization involves not merely the introduction of machinery but also its utilization on farms. Therefore, training of operators and improving field conditions are also very important for promoting farm mechanization.

Outstanding advances in agricultural biological sciences aid mechanization, as for example, when plant breeders produce varieties better suited to mechanical transplanting of rice. Cultural practices for some crops are changed in order to modify the growth habits and obtain plants better suited to mechanical operations.

Further simplification and standardization of the attachment methods for tractor-mounted equipment would be helpful to the farmer.

In the public stations, the ultimate goal of research is to obtain a product that is useful and acceptable to the farmer and the Government. From our experience, it seems to be very important that farm management research on mechanization be undertaken systematically with co-operation between the staffs in farm management and other fields.

[1] Roy Bainer, R.A. Kepner, and E.L. Narger, *Principles of Farm Machinery*, New York: John Wiley & Sons, 1965.

[2] T.H. Lee, *Agricultural Development and its Contributions to Economic Growth in Taiwan*, JCRR, Econ. Digest Ser. No. 17, 1966.

[3] Nobufumi Kayo and others, *Problems in Japanese Farm Mechanization*, 1962 (in Japanese).

[4] Many different opinions were expressed prior to 1960 regarding economic evaluation of the power tiller in Japanese agriculture. Some of these were based on the mistaken idea that use of loans to finance the purchase of power tillers would impoverish farmers. Experience has disproved this view.

[5] The First Project has been carried on successfully for the past ten years. The aims of this Project relate mainly to land improvement and farm mechanization.

[6] Agriculture, Forestry and Fisheries Research Council, *Rational Management of Rice Center*, 1966 (in Japanese).

[7] Z. Kudo and others, *Development of Tractor Farming in Tohoku Region*, Res. Rep. No. 39, Research Council of Ministry, 1969 (in Japanese).

[8] For instance see: Z. Kudo, *An Economic Study of Farm Machinery on Japanese Family Farms*. Tohoku Natl. Agr. Exp. Sta. No. 25, 1962 (in Japanese).
Deep plowing is one of the most important effects, as described by T.H. Lee, but it is a secondary effect, realized through increased yield of crop, and connected with fertilization and soil productivity.

[9] Akira Takei, *Farm Mechanization in Japan*, 1971 (in Japanese).

[10] Morishige Matsuzawa, *Family Farm and Farm Machine*, 1958 (in Japanese).

[11] Keizo Tsuchiya, "The Role and Significance of Mechanization in Japanese Agriculture", *J. of the Faculty of Agriculture, Kyushu Univ.*, 16(2), 1970.

[12] Toshimi Umeki, *Effects of Power-tiller Use on Farm Income in the Saga Plain Area, Saga Prefecture, Japan*, Dept. of Agricultural Economics, Kyushu Univ., English Bul. No. 3, 1961.

[13] Z. Kudo, *Economic Study of the Replacement of Power Tiller on Shonai Farms*, Tohoku Natl. Agr. Exp. Sta. Bul. No. 37, 1969 (in Japanese).

[14] National Institute of Agricultural Sciences, *Research Tendency and Subjects of Farm Management and Rural Life*, 1969 (in Japanese).

[15] Tadao Yoshikawa and others, *Development of the Pilot Farms Founded at Bonbana on the Hillside of Mt. Iwate, 1960–1965*, Tohoku Natl. Agr. Exp. Sta. Bul. No. 41, 1970 (in Japanese).

MECHANIZATION FROM THE STANDPOINT OF LOCAL GOVERNMENT: EXPERIENCE IN A JAPANESE SUBURBAN AREA

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The purpose of this paper is to review the development of farm mechanization in Kanagawa Prefecture, Japan, and to show the socio-economic factors or conditions by which farm mechanization has been influenced.

Kanagawa Prefecture (K.P.) is located in southwestern Japan near the Tokyo metropolis. Its total population in 1971 was 5.5 million, and it has been increasing by more than 200,000 people a year (Table 1). In contrast, the farm population has been decreasing rapidly. It numbered 332,000 people in 59,000 farm households in 1970. The percentage of farm population in total population has been decreasing even more sharply because of urbanization by the Tokyo metropolis.

Conditions Affecting Mechanization in Suburban Agriculture

In recent years, with the rapid growth of the national economy, young and good farm laborers in suburban areas have moved into urban industrial, commercial and service districts in large numbers, leading to a shortage of farm labor. Hence farm mechanization is becoming increasingly important.

The need for farm mechanization is affected by two further conditions:

1. The people remaining on farms and doing the farming are old folks, children, and women. They are not so able to use farm machines and implements, especially the large, heavy, complicated equipment.

2. Joint operation and contract use of machinery are becoming important.

In K.P., the land area is not large, but there is a big output of industrial products in Yokohama, Kawasaki, and inland industrial cities. Statistics show the small share of the agricultural sector in the K.P. economy (Table 2).

Farmers in K.P. are becoming "decimal people" under intense pressure of urbanization. The increasing numbers of people in

Table 1. Total Population and Farm Population in Kanagawa Prefecture, 1950–70.

Year	Total population		Farm population		Ratio (B/A)
	Number (A)	Index 1950 = 100	Number (B)	Index 1950 = 100	
	(1,000 persons)	(percent)	(1,000 persons)	(percent)	(percent)
1950	2,487	100	565	100	22.7
1955	2,919	117	520	92	17.8
1960	3,443	137	460	81	13.4
1965	4,430	178	397	70	9.0
1970	5,470	220	33.	59	6.1

Table 2. Agriculture's Share in the Economy of Kanagawa Prefecture, 1960–70.

Year	No. of farm households / Total no. of households	Area of farm land / Total land area	Gross agricultural product / Gross industrial product	No. of farm laborers / Total no. of laborers
		(percent)		
1960	9.1	26.2	2.4	9.0
1965	5.8	21.4	1.6	5.5
1970	3.8	17.6	1.2	3.9

need of homes hunt for cheap farm, forest, and hillside land. Rising prices of land, rising wages, and problems of pollution are three main things that discourage farmers from continuing in farming and prevent them from enlarging their farms.

However, farmers are blessed by nearby markets and by investments of public, social, and private enterprises and amenities in the urban areas, such as dial telephones and paved roads for easy driving. By-products of food factories and table scraps from restaurants provide feed for raising livestock (Table 3).

Table 3. Merit and Demerits of Continuing Farming in K.P.

Merits	*Demerits*
1. Easy access to nearby markets.	1. High and rising price of land.
2. Use of urban services provided by public and private social capital investment.	2. High and rising wages.
	3. Pollution problems.

Under these circumstances it is necessary to mechanize farms in order to protect those farmers who wish to use their lands productively, not simply hold them for speculative purposes in expectation of rising land prices.

Fortunately, the rising price of farm land and the large deposits in the Agricultural Cooperative Association (A.C.A.) make it easy for farmers to borrow money for mechanization. Local governments arrange credit through the institutional loan system sponsored by the National Government. Consequently, some upper-class farmers borrow much money, even though they are millionaires, to develop capital-intensive farming.

Characteristics of mechanization in suburban agriculture

What form does mechanization take in the management of suburban farms? It has special meanings, in that suburban farmers carry on different types of farming to meet the demand for fresh produce and to supply the main outlets for unusual products.

For instance, there are vegetable farmers near Yokohama harbor who sell products to ships' chandlers. They produce long-lived cabbages that are not juicy but that keep their freshness in storage during a voyage.

Endive for western salads also brings a good price; if sold in wholesale markets it would undoubtedly bring a lower price.

Some farmers produce seedlings of cycads, pineapple, and cactus in vinyl houses and sell them direct to ultimate consumers who visit their farms or come to nearby resorts along the coast of Sagami Bay.

We thus find many unique types of farms in K.P., and generally speaking, operators of these farms have two objectives in mechanization. One, needless to say, is to save labor. The other is artificial control of natural conditions. The former mainly involves self-propelled or, in some cases, stationary machines and implements. The latter mainly involves installations and equipment such as greenhouses or vinyl-covered houses with automatic irrigation, heating, steam sterilization of soil, air cooling by water, air conditioning, automatic ventilators, etc.

I must emphasize the importance of the latter type of mechanization in suburban farming. Friends tell me that such capital investment is not really mechanization. However, I deal with both types of mechanization, using the term in a broad sense, in this paper.

The question of over-investment

Table 4 shows the rapid change in numbers of full-time and part-time farms in K.P. in the last decade. We find suburban agriculture dividing into two classes of farm households under the influence of urbanization. One is an upper class of developed farms with a reasonable size of business, obtaining income mostly from commercial agriculture. The other class have less enthusiasm for farming, operating with low-quality farm labor and depending mainly on non-agricultural income.

Both face a shortage of labor, but in different senses. The former class carry on extremely intensive mechanized farming. The latter are part-time Sunday farmers. Both classes hope to introduce farm machines in order to raise labor efficiency. With the high growth of the economy it is not easy to hire employees

Table 4. Number of Full-time and Part-time Farms in K.P., 1960–70.

Year	Total no. of farms	Full-time	Part-time: Mainly farming	Part-time: Mainly non-farming	Farmland per farm
					(hectares)
1960	73,873 (100)	20,733 (28.1)	24,914 (33.7)	28,226 (38.2)	0.71
1965	66,738 (100)	14,476 (21.6)	20,537 (30.7)	31,725 (47.4)	0.66
1970	58,949 (100)	9,843 (16.7)	15,565 (26.4)	33,541 (56.9)	0.63

for farming because of the high level of wages in non-agricultural employment. In these circumstances, both classes wish to introduce machines and implements. They have no time to calculate the cost of idle machinery. Convenience of farm operations is more important than such economic considerations in their farming.

The scale of measurement of "over-investment" in suburban agriculture differs because of the location of farms, especially the high price of farm land and the rising trend. In a proper approach to farm management, over-investment of capital reduces profit. Needless to say, the upper-class farmers are pursuing profits by accelerating mechanization even though there appears to be "over-investment". Having enough machinery means good timing of operations, control of the harvesting season, adjustment of land use without idle fields, and farmers' ability to do things when they choose by using their own machines.

Although the part-time farmers are pursuing non-agricultural profit, they also want their own machinery. To them it brings the advantage of free and leisure time through reduction in working hours and avoidance of physical exhaustion from heavy farm work.

Background of Mechanization of Farming in the Great Tokyo Metropolis

Characteristics of farming in K.P.

Agriculture in K.P. has the following fundamental characteristics:

1. Great decrease in the numbers of farms by classes (Table 4) and the loss of enthusiasm for agriculture.
2. Decrease in cultivated land and increase in waste farm land (Table 5).
3. Rapid decrease in the agricultural labor force due to absorption into the non-agricultural sector.
4. Division into highly productive full-time farms and less productive part-time farms. The smaller numbers of highly productive farms produce more valuable products by specialization. Their size of business is large even though their area of farm land is small.
5. Specialization in horticultural farming, due to its profitability compared to other crops.

Table 5. Area and Percentage of Waste Land on Farms in K.P., 1970.

Classification	No. of farms	Waste land (A)	Total farm land (B)	(A/B)
		(hectares)		(percent)
Full-time farms	1,853	389	9,701	4
Part-time; mainly farming	7,290	1,607	14,273	11
Part-time; mainly non-agriculture	5,840	772	12,911	6
Paddy field	4,923*	634	11,407	6
Ordinary upland fields	11,542*	2,094	19,337	11
Orchards	266*	40	6,141	1
TOTAL	14,983	2,768	36,885	8

* Some farms had more than one type of land.

I have advocated that the contribution and role of agriculture in "metropolitan farming" is two-fold: to supply fresh foods direct to ultimate consumers, and to provide green open spaces and oxygen for city people.

Rice production is still the mainstay and predominant type of farming in Japan. However, in metropolitan agriculture it is not so important because of the low value productivity per hectare and the competition for use of water between city and paddy. Besides, large cities are located on alluvial plains of the lower stream beds of rivers, so that wet paddy fields predominate around these cities; but urbanization is accompanied by pollution, and dirty water in paddy causes low rice production.

Development of farm mechanization in K.P.

As mentioned above, farm mechanization in K.P. has involved investment of capital in both farm equipment and farm installations. As regards the usual types of machines, contributions have been made to increase production over the past 10 years (Table 6) by using highly efficient tractors, trucks for transportation, and power sprayers and dusters, as well as stationary machines for processing. Nowadays, joint control of diseases and insect pests has begun to be practiced. Power reapers and small harvesters and planters are in practical use in paddy fields. An outline of this development in K.P. follows:

Power tillers (Fig. 1)

Pulling (plowing) type: Merry tiller (3 to 4 HP) until 1960; bonnet type (4 to 6 HP) since 1960. Recently being replaced by other types.

Rotary type: Gradual increase; mini-cultivators now becoming popular. Importance enhanced by appearance of weed killers.

Type combining both functions (plow and rotary cultivator parts are interchangeable).

Riding tractors (Fig. 2): initially under 15 HP, then more than 20 HP if privately owned and about 40 HP if owned by a cooperative group for agricultural production, A.C.A., etc.

Trucks for transportation (Fig. 1): found on many farms; tricycle trucks decreasing year by year.

Fig. 1. Numbers of Power Tillers and Trucks on Farms in K.P., by Type, 1960–70.

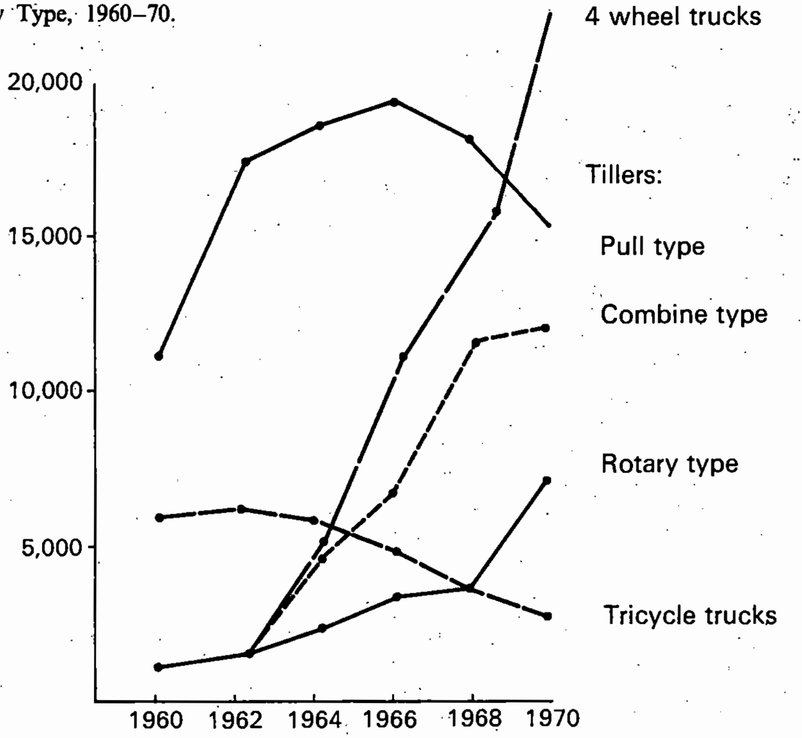

Fig. 2. Number of Riding Tractors on Farms in K.P., 1964–70.

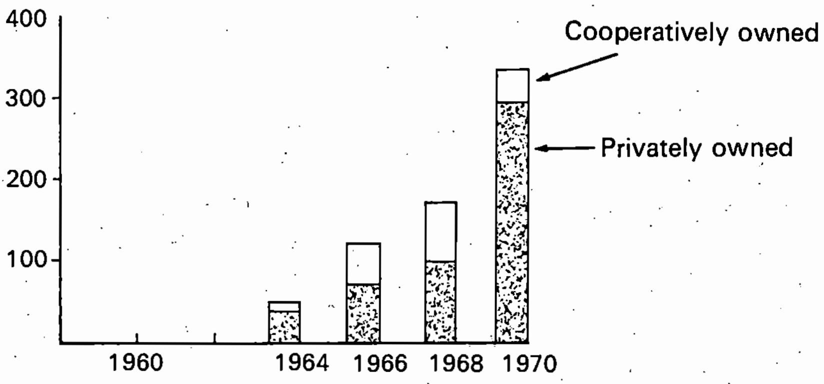

Table 6. Numbers of Farms, and Proportion of All Farms, Having Specified Types of Machinery, K.P., 1960–70.

Year	Tillers, tractors	Trucks, tricycles	Sprayers	Dusters	Percentage of all farms			
	1	2	3	4	1	2	3	4
1960	12,187	6,319	4,660	953	16.5	8.6	6.3	1.3
1965	30,962	15,522	8,894	2,428	46.4	23.3	13.3	3.6
1970	38,747	21,493	13,946	5,078	65.7	36.5	23.7	8.6

Note: Total number of farms was 73,873 in 1960, 66,738 in 1965 and 58,949 in 1970.

Tricycle trucks for farm use were introduced in Miura peninsula, K.P., in 1951. Our investigation found that early introducers changed from joint-marketing crops (potatoes, radishes, and wheat) to new crops suitable for private shipping (tomatoes, cucumbers, and cabbages). Thus we found that mechanization of transportation alone affected the type of farming. ("Truck farming" means suburban agriculture.)

Mechanization in Horticultural Farms in K.P.

Vegetable farms

Vegetables may be divided into two groups: (1) intensive vegetables; (2) comparatively extensive vegetables, in which mechanization in the customary sense is easy (Table 7).

Table 7. Adaptability for Mechanization of Groups of Vegetables.

Characteristic	Intensive vegetables	Comparatively extensive vegetables
Means of production:	Man power and equipment	Machines and implements
Size of crop planted:	Small	Rather large
Quality of commodities:	Excellent	Fair
Income per hectare:	High	Fair
Labor income per hour:	Not so high	High
Number of crops on a farm:	Many, small output of each crop	Few, large output
Stability of price:	Stable	Unstable
Cost of production:	High	Low

Degree of mechanization of extensive vegetables:

Mechanized throughout	Onions, carrots, potatoes
Mechanized except for harvesting	Radishes, Chinese cabbage, cabbage, spinach
Mechanized except for planting and harvesting	Welsh onions, watermelons, cucumbers

Some problems of the vegetable farms are small size (Table 8), scattered farms (Table 9), and dependence upon older laborers (Table 10). These conditions make it difficult to promote mechanization.

The proportion of vegetable farms that have various kinds of machines is shown in Table 11, and the remarkable development of horticulture under vinyl and glass in Table 12.

Table 8. Numbers of Vegetable Farms and Distribution by Area Planted to Vegetables.

	Number	Percent
Farms planting vegetables	35,150	100
Farms selling vegetables	17,320	49.3

Area planted to vegetables	Proportion of farms
(hectares)	(percent)
Less than 0.3	48.5
0.3–0.5	19.9
0.5–0.7	11.1
0.7–1.0	9.1
More than 1.0	11.4
Total	100.0

Table 9. Scattering of Farmers' Vegetable Fields and Fruit Orchards

No. of plots per farm	Proportion of farms	
	Vegetable	Fruit
	(percent)	
1	25.8	40.2
2	22.1	25.0
3	19.8	22.7
4	14.7	
5 or more	17.6	12.1
Total	100.0	100.0

Table 10. Age Distribution of Workers on Vegetable and Fruit Farms.

Age	Proportion of Workers	
	Vegetable farms	Fruit farms
(years)	(percent)	
30 or less	10.7	14.0
31–50	51.3	47.7
51–60	16.5	20.2
Over 60	21.5	18.1
Total	100.0	100.0

Table 11. Mechanization on Farms Selling Vegetables.

Machine	Proportion of farms
	(percent)
Power tiller	91.3
Truck, tricycle	56.4
Sprayer	45.0
Car	37.4
Duster	15.5
Riding tractor	1.1

No. of farms: 17,320.

Dotted among the other farms are many that raise garden trees and flowers (Table 13). On the garden-tree farms, 62 percent of the area is in many kinds of nursery stock. The pot-plant farms include raisers of flowering plants (40 percent) and foliage plants or succulents (60 percent).

Fruit Farms

The fruit farms are very similar to the vegetable farms except for the long-term capital investment in orchards. They are somewhat more commercialized than the vegetable farms, but the orchards are likewise small (Table 14). They are somewhat less scattered than the plots of the vegetable farms (see Table 9).

Fruit farmers invest in sprayers and water reservoirs for prevention of diseases and insect pests, as well as in storage facilities (Tables 15 and 16). In K.P., oranges are a leading product in

Table 12. Area of Horticultural Crops Grown Under Vinyl and Glass.

Crop	1965 (A)	1970 (B)	(B/A)
	(hectares)		(ratio)
Tomatoes	21.5	62.4	2.9
Cucumbers	6.3	46.4	7.4
Egg plant	0.5	3.3	7.0
Strawberries	16.4	37.9	2.3
Other vegetables	4.2	22.0	5.3
Flowers	22.6	47.9	2.1
Total	71.5	220.9	3.1
No. of farms using vinyl and glass	1,698	2,934	1.7

Table 13. Numbers and Crop Areas of Farms Raising Ornamental and Related Crops.

Type of farm	No. of farm	Total area
		(hectares)
Garden-tree farms	722	251.0
Sod farms	692	272.0
Pot-plant farms	187	5.7
Cut-flower farms	833	40.0

hilly areas (Tables 17 and 18). About half of the production is stored until March or April. Of the other fruits, our investigation shows that 70 percent are sold directly to consumers at roadside stands or at orchards.

Table 14. Numbers of Fruit Farms and Distribution by Areas of Orchards.

	Number	Percent
Farmers growing fruit	12,140	100
Farmers selling fruit	8,860	72.9

Orchard area	Proportion of farms
(hectares)	(percent)
Less than 0.3	34.3
0.3–0.5	25.1
0.5–0.7	17.1
0.--1.0	9.4
1.0–1.5	10.7
More than 1.5	3.4
Total	100.0

Table 15. Mechanization of Farms Selling Fruit.

Item	Proportion of farms
	(percent)
Power tiller	66.8
Sprayer	62.4
Truck, tricycle	51.7
Water reservoir	36.1
Car	34.8
Storage facility	29.2
Duster	5.9
Riding tractor	0.7

Table 16. Distribution of Farms Selling Specified Fruits by Number of Treatments for Control of Diseases and Insect Pests.

Fruit	Number of treatments				
	5 or less	6–10	11–15	16 or more	Total
	(percent of farms)				
Orange	59.4	37.8	2.8	–	100
Pear	8.1	9.5	41.5	40.9	100
Peach	38.1	35.5	22.6	3.8	100
Kaki	81.2	16.7	2.0	0.1	100

Table 17. Areas of Specified Fruits in K.P., Actual and as Percentage of Japanese Total.

Fruit	Area	Share in Japan
	hectares	percent
Orange	3,850	2.6
Chestnut	565	1.6
Kaki	429	1.1
Pear	312	1.7
Plum	159	1.0
Grape	114	0.5
Peach	63	0.3

Table 18. Types of Land Used for Orange Orchards in K.P.

Type of Land	Percent
Terrace	38.8
Steep slope	9.0
Slope	35.4
Plain	16.8
Total	100.0

Source: Statistics on Agricultural Mechanization in Horticulture, Agri. Survey, 1968.

K.P. Government and Related Organizations Concerned with Mechanization

Agricultural Extension Service

An Agricultural Extension Service (A.E.S.) was started in K.P. in 1949, and now 121 farm agents and 28 home agents as well as 12 subject-matter specialists serve the 59,000 farms. Seven of the extension agents and a machinery specialist stationed at the Agricultural Experiment Station devote themselves to popularization of mechanization, especially through educational activities on use of machines.

In guidance work on mechanization a target is set for extension activities on each crop. For example:

1. On field vegetables: introduction of mechanization, work simplification, and promotion of specialization in order to enlarge cropping areas.
2. On vegetables in vinyl and greenhouses: improvement of automatic control equipment and management, as well as prevention of noise from boilers and fans.
3. On flowers in greenhouses: steam sterilization of soil.
4. On foliage pot plants and garden, street, and park trees: propagation in greenhouses equipped with automatic mist sprayers.
5. On fruit tree farms: joint use of large machines and cold storage methods.
6. On livestock and poultry farms: introduction of automatic feeders, barn cleaners, and windless barns in order to save labor, reduce cost of products, and avoid pollution problems.

The main role of the specialist is to train extension agents in extension methods, provide educational publications, and demonstrate methods of handling machinery.

Agents serve farmers directly or in groups. They also keep close contact with technicians in A.C.A.

There is a Machinery Training Section in the Agricultural College of K.P. under the A.E.S. where three technicians conduct long and short term training courses for young farmers. Qualifying examinations for driving licences for riding tractors are given at the College.

K.P. Government Loans and Subsidies for Mechanization

Agricultural administration in the Kanagawa Prefectural Government (K.P.G.) is mainly carried on in seven sections. The Agricultural Administration Section has exclusive charge of loans. The Horticultural-Food, Livestock, Forestry, and Fishery Sections supervise subsidy activities in each commodity line. K.P.G., of course, manages both subsidies and loans for each project.

Table 19 lists the loan programs providing credit for mechanization. Further information follows:

1. The *Fund for Agricultural Improvement* is intended to promote introduction of new techniques, so loans are provided for new machinery and for installation of rice seedling planters, fan-heater devices, nature desiccators, transportation by monorail in orchards, etc. If a group of farmers wish to undertake a joint-use project, they can obtain a loan to buy a complete set of machinery, as shown in Table 20.

Table 19. Sources of Loans for Farm Mechanization in K.P.G.

Loan program	Year started	Sources of funds
(1) Fund for Agri. Improvement	1956	National and Pref. finance
(2) Fund for Agri. Moderniza-tion	1961	A.C.A. and A.C.A. of Credit
(3) Fund for Farm Management Rationalization (K.P.)	1961	A.C.A. and A.C.A. of Credit
(4) Fund for Agri. Finance Corporation	1953	National finance
(5) Fund for Agri. Development (K.P.)	1950	Pref. finance and A.C.A. of Credit
(6) Fund for Agri. Reclamation	1947	National finance and Federal A.C.A.
(7) Fund for Disaster	1955	A.C.A.

Table 20. Limitations on Loans for Complete Sets of Machinery, 1971.

Type of farming	Minimum area	Maximum loan
	(hectares)	
Vegetables	5	¥ 935,000
Sericulture	5	720,000
Rice and wheat or barley	5	660,000
Forage	10	1,400,000

2. The *Fund for Agricultural Modernization* is a main fund for loans to buy machinery and implements. Its loan limit is ¥2,000,000 for an individual, ¥10,000,000 for a legal person, and ¥50,000,000 for a joint-use installation.

3. The *Fund for Farm Management Rationalization* has been instituted by K.P.G. for the same purpose in order to meet additional needs of farmers. The other funds listed in Table 19 also provide some kinds of loans for mechanization.

The annual total of loans in K.P. has increased rapidly, from 378 million yen in 1960 to 2,004 in 1965, 2,651 in 1969, and 3,266 in 1970. The demand for loans for machinery is rather high, although the amount of money per case is small. The demand for loans for equipment and installations comes from livestock and horticultural farms. Of 537 agricultural machinery and implement loans in 1969 (Table 20), 488 were provided from the *Fund for Agricultural Modernization*, 33 from the *Fund for Agricultural Finance Corporation*, and 16 from other funds.

The Public Interest in Mechanization of Metropolitan Agriculture

As mentioned above, land prices in this sprawling area are going up as a result of urbanization and inflation. Thus farm land has a high mortgage value, and farmers find it easy to borrow for capital investment in their farms. However, the demand for agricultural funds is seasonal, and there are problems of idle capital due to low levels of operation and calling in of long-term loans.

Table 21. Distribution of Loans by Objectives, and Amount of Money per Case, 1969.

Objectives	Percent of total amount	Amount per case	Number of cases
A.C.A. project	30.6	¥16,561,000	49
Livestock farms	25.1	1,299,000	512
Joint-use installation	8.9	47,236,000	5
Agri. machinery & implements	6.4	316,000	537
Flower farms	5.8	1,323,000	117
Fruit farms	4.1	619,000	177
Land improvement and consolidation	3.8	1,486,000	68
Vegetable farms	3.2	417,000	205
Stability for farm, disaster etc.	12.1	—	423
	100.0	1,267,000	2,093

Accordingly, the supplying of funds is risky; yet agricultural loans should be at a low interest rate and with a long redemption period. The characteristics of agricultural production — the long production period, busy and non-busy seasons, small size of farm business, unstable prices, etc.—create a need for national and local governments to provide special types of loans as a matter of public policy. Interest rates of city banks are too high.

From the standpoint of farm management, a low interest rate increases farm profit. On the other hand, too low an interest rate imposes a heavy financial burden upon national and local governments. However, it is necessary to subsidize reliable and responsible farmers through either loans or subsidies even if this involves over-investment. To keep green open spaces in metropolitan areas is important to the health in mind and body of people in a highly industrialized urban society. There is an urgent need to enable metropolitan farms to survive and develop in harmony with the urban environment.

Table 22. Analysis of Farm Household Economy, K.P., Compared with Average of 45 Prefectures, 1969, and Relative Rank of K.P. Among Prefectures, 1969 and 1965.

(Unit: ¥1,000 except as noted)

Item		Average of 45 prefectures	K.P.	Rank of K.P.	
				1969	1965
Farm family income	(1)	1,252.3	1,911.6	1	2
Agri. income	(2)	515.8	600.3	9	14
Agri. gross income	(3)	932.1	1,182.0	2	4
Agri. expenditures	(4)	416.3	581.7	2	2
Non-agri. income	(5)	736.5	1,311.3	1	4
Area of farm land (ha.)	(6)	0.921	0.777	26	17
Agri. working hours (hr.)	(7)	2,789	2,994	15	13
Agri. fixed capital	(8)	1,026.0	1,198.0	9	5
Machinery and implements	(9)	179.8	135.2	39	41*
Trucks, tricycles and cars	(10)	107.0	236.0	2	1*
Ratio of agri. income (percent)	(2)/(3)	55.3	50.8	35	40
Ratio of fixed capital (yen)	(8)/(7)	3,679.0	4,001.0	14	14
Agri. working hours per hectare (hr.)	(7)/(6)	3,030	3,820	7	19
Agri. fixed capital per hectare	(8)/(6)	1,114.0	1,542.0	7	10
Agri. income per 10 hours (yen)	(2)/(7) ×10	1,911.0	2,054.0	16	17
Agri. income per ha.	(2)/(6)	579.0	791.0	3	15
Agri. income per 1,000 yen of agri. fixed capital (yen)	(8)/(2) ×1,000	520.0	513.0	21	28*
No. of farms analyzed		10,185	118		

Source: Survey Report on Farm Households Economy, M.A.F. 1971.
* as of 1967

FARMER MOTIVATION FOR MECHANIZATION

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Agricultural development in Taiwan has been very remarkable. With all its achievement, however, Taiwan's agriculture until quite recently remained primitive as far as farm machinery and implements are concerned. It was developed with eyes on the scarce land resource and the highest returns therefrom, not on the efficiency of farm labor, which, being an abundant resource, had very low productivity and therefore almost no value whatsoever.

Most of the effort on improving agriculture in the past was concentrated on the construction of irrigation and drainage systems, experimentation on breeding and multiplication of new seeds, fertilization, pest and disease controls, etc. All these contributed much to agricultural production through the rise in yield per unit area.

In contrast, very little attention was given to the farm mechanization side of agricultural production. Farm machinery and implements were almost wholly neglected in the improvement of Taiwanese agriculture.

A brief history of farm mechanization in Taiwan

For several centuries before Taiwan became a colony of Japan in 1895, there had been little change either in agriculture or in the design of farm implements. Then Taiwan's agriculture began to show rapid progress. But with the exception of a few farm implements that were modified forms of those used in Japan, most of the farm implements in use in Taiwan were exactly the same, simple, primitive ones of the pre-Japanese days.

True, farm machines such as tractors were seen in Taiwan fields in the Japanese days. However, they were exclusively used in the sugar-cane plantations. There is nothing wrong in citing this as the first farm machine ever to be introduced to agricultural production in Taiwan, but it would be a serious error to think that Taiwan's agriculture entered into the mechanization era with the introduction of tractors on the sugar-cane plantations. For it is the small peasant farmers' subsistence sector, not the plantations, that really represent Taiwanese agriculture. And mechanization of that sector, all through these years, remained in the stage of using rather few primitive agricultural implements.

After the end of World War II, nearly a decade passed without any noticeable change in farm mechanization. The centuries-old stationary condition of Taiwanese agricultural mechanization was first broken in 1954, when the Joint Commission on Rural Reconstruction introduced seven foreign-made small power tillers to Taiwan.

These first power tillers were tested in the experimental stations. Gradually power tillers found their way on to peasant farms, and their number exceeded 2,000 when the Department of Agriculture and Forestry, Taiwan Provincial Government, satisfied with the experimentation, announced its plan of initiating the "Farm Mechanization Extension Project" in 1959.

The project can hardly be called successful, for so far the pace of mechanization in Taiwan's agriculture—represented by increase in number of power tillers—has been slower than anticipated. Even the prefecture in which power tillers enjoyed highest popularity had only around 50 of them for every 1,000 farms or 1,000 ha. of arable land.[1] These ratios are certainly much lower than the corresponding ratios in Japan.

In contrast to power tillers, water pumps were more rapidly adopted on Taiwanese farms. Available data show that there were 8,378 water pumps in 1960. They spread quickly and increased more than 5 times during the following 9 years.

Still another major farm machine in Taiwan is the mist blower or duster, the latest of the three. There were only 317 of them in Taiwan in 1960, but the increase was most amazing. In 1969, the number reached 14,800; that is, there were nearly as many mist blowers or dusters as power tillers in rural Taiwan.

Outline of the paper

With this brief sketch of the history of farm mechanization in

Taiwan, we shall proceed to consider various motivational aspects from the individual farmer's viewpoint, in order to understand the process of farm mechanization more fully.

First, our investigation will be focussed on farmer motivations for introducing machinery: the conditions that are necessary, favorable, or unfavorable for farm mechanization. Farm machines may be introduced to farming operations on several bases: private ownership for use on the farmer's own farm, private ownership with the purpose of self-use plus renting out for "custom work" to increase farmer's cash income, cooperative ownership and joint use by a group of owner-farmers, or ownership by a cooperative that provides machine service to its member farmers.

Although exclusive individual ownership is most common, joint or cooperative ownership is by no means rare. So we shall also give attention to the cooperative side of farm mechanization.

Then we shall consider the effect of mechanization on inputs and input combinations, especially on labor intensity and degree of machine utilization. However, the effects themselves are not our major concern; our major concern is farmers' reactions to them—the secondary farmer motivation after experiencing mechanized farm operations, i.e., the effect-motivation links of mechanization.

Effect-motivation links are not limited to inputs; similar links are established through enterprise combinations (crops and/or livestock), and these will be studied also. Furthermore, as farmers' experience with mechanization accumulates, eventually they look into possibilities of basic change in the whole farming system that can co-ordinate machines nicely, smoothly, and systematically; i.e., they move toward more mechanically oriented ways of farming. So this eventual reaction of farmers must likewise be studied. Also to be studied is the replacement motivation, as any machine must be replaced at some later point of time.

After examining primary and secondary farmer motivations for farm mechanization, we shall briefly study those motivations that arise from viewpoints other than that of farm management. A final section will summarize conclusions.

Throughout the study we shall concentrate mainly on the power tiller as representative of farm machines in Taiwan. By the same token, we shall not consider mechanization of plantation farming.

Primary Farmer Motivation for Initiation of Mechanization

Necessary conditions

Although there is still much self-sufficiency in the peasant farm economy, farmers in present-day Taiwan can operate only within the huge framework of Taiwan's economy. This means that farmers calculate the costs and returns of any change in farm organization and management before they reach a final decision.

Farm mechanization, of course, is no exception. Thus the first necessary condition for initiating farm mechanization is a favorable cost-returns calculation that assures farmers more profit from their farms or higher farm family income through mechanizing. Let us look more closely into this aspect of farmers' decision making on mechanization.

First, let us examine this problem historically. In the pre-land-reform days, the prevalence of landlordism had much to do with farm mechanization. In my view, landlordism makes farm mechanization almost impossible. In the pre-land-reform days, when farm tenancy was very common, those farmers who possessed more land than they could operate with their family labor found it much more profitable to lease out their excess land and collect rent than to operate all the land they possessed by themselves. In fact, bigger landlords used to lease out all of the land in their possession without retaining any of it under their own management.

Small farmers who felt that the land they owned was not large enough to absorb the available family labor were in the opposite situation. These farmers were the counter-part of the landlords; they sought others' land in order to utilize fully their family labor.

The point here is not so much the rise and spread of landlordism but the farmers' desire of full utilization of family labor, made possible by renting land. This desire, in turn, stemmed from farmers' regarding their family labor as having no cost. As long as farmers thought and acted in this way, mechanization was impossible, as seen both in Japan and in Taiwan before the recent land reform. There were a few "semi-machines," more complicated than implements but still operated not by power-engines but by human labor or cattle, and all were designed for the processing of harvested crops, such as pedal threshers and winnowers.

The contrast between concentration on semi-machinery for post-harvest operations and the total neglect of mechanization for field tasks during crop-growing reflects the way in which the predominance of the landlord's interest at that time influenced the agricultural machinery development process.

To peasant farmers, family labor was free of charge, whereas mechanization would mean an increase in cost. Family labor was not a cost item, it was a part of income. More work on the part of family labor meant additional income, as embodied in the labor-earning concept, rather than additional cost.

In this situation, peasant farmers would not initiate farm mechanization because no matter how efficient the machines might be they could not beat free-of-charge family labor. As a result, agriculture developed a labor-intensive way of cultivation.

That was the story in the long period before land reform. With the enforcement of the land reform, landlordism collapsed and a new power, that of the owner-tiller, emerged. The land-lease market, which was so widespread and played such an important role in the old farm tenancy system, disappeared.

In the early days of land reform that raised no problem, because peasant farmers, now owner-tillers, were supposed to possess farms of just about the right size for their existing amount of family labor. But as time passed, some peasant farmers found their farms becoming too big for them to manage, owing to the out-flow of family labor to the non-agricultural sector, to their entering the shrinking stage of the family cycle, or even to the draft, schooling, sickness, or retirement. And other farmers found themselves in just the opposite condition: family labor increased because family members finished school, were released from the service, etc.

When this happened in the pre-land-reform days, both types of farmers would meet in the land-lease market and each would be glad to expand or contract the size of his farm through rental arrangements. However, in the post-land-reform days, although the latter type of farmer would still want to rent land from others, there would be no opposite party. The former type of farmer, being discouraged by the protective regulations in favor of the tenant, would seldom wish to lease out his land. Instead of leasing or renting land to accomodate changes in family labor, both groups turned to hiring or offering labor, keeping the sizes of farms unchanged.

The natural outcome of this is mechanization. Farmers without enough family labor to run their farms have to consider either hiring agricultural laborers or introducing farm machinery. If the latter becomes cheap enough, which occurs once the economy is sufficiently industrialized, farm machinery gradually finds its way into peasant farming. And as soon as family labor becomes inadequate, so that farmers have to rely upon hired labor, family labor ceases to be a free factor any longer. Now, family labor comes to be reckoned by the wage rate; it becomes a cost item, just like machinery. The discovery that labor, hired and family labor alike, costs money leads farmers to economize on labor, and this, in turn, leads them eventually to mechanization as the efficient, economical way of doing the farm operations.

In the preceding analysis we sought the necessary conditions for farm mechanization by contrasting conditions prevailing before and after land reform. The presence or absence of the land-lease market was the central element around which our investigation developed. Another important element appears in the above analysis: the shift of power in the rural economy from the landlords to the owner-farmer peasants, caused by the land reform.

Along with farmers' finding that labor costs money, farmers' reaction that "time is money", learned from their now busier social life, has contributed to farm mechanization.

In pre-land-reform days, the social as well as the economic life of rural people was controlled by the landlords. Landlords could successfully perform this function by leaving the management of land to the tenants.

After land reform, power changed hands. The tasks that had been carried out by the landlords now had to be done by the peasant farmers. They became busy attending meetings and engaging in various social activities in addition to their own business, farming.

These all take time, so they came to feel short of time. The "time is money" attitude involves the concept of efficiency, and farmers turn to time-saving methods in place of the labor-consuming ways of farming they used before. It does not take too long until they find a wide range of machinery waiting for them to adopt. The auto-bike has a great appeal, as have many kinds of farm machinery, because farm people now live a busy "time is money" social life.

Conditions favorable for spread of mechanization

We have seen that as the institutional framework undergoes changes, either by social force, like legislation, or by economic force, like industrialization, or both, peasant farmers eventually come to appreciate the scarcity and hence the value of labor. This new attitude toward labor leads them to search for more efficient labor-saving ways of crop production. It is under these conditions that mechanization comes to be introduced in farm operations.

We shall now turn to the forces that govern the pace of spread of farm machinery in peasant farming.

Theoretically, since motivation for initiating farm mechanization lies in the efficiency of farm machinery as compared to the traditional labor-intensive way of farming, anything that makes farm machinery either more efficient or less costly, so that mechanization proves to be more profitable (either in the narrower farm-income sense or the wider farm-family-income-sense) will bring about mechanization.

Specifically, anything that causes agricultural labor shortage, with a resultant rise in agricultural wages, will strengthen the competitive (substitutive) capacity of farm machinery.

Furthermore, labor shortage is also a comparative term. It may come directly from a decrease in the absolute number of agricultural laborers, resulting from, say, an out-flow of farm family labor to the non-agricultural sector. It may come indirectly from improvement in the cropping system (i.e. increase in the cropping index) in the face of, say, a constant amount of labor force in agriculture or even despite a slight increase in labor force.

Increase in the cropping index tends in practice to make the labor requirement more concentrated in a few months of the growing season. As a result, peak-period labor pressure is more keenly felt, and the time span permitted for completing each task becomes shorter. All these things increase farmers' appreciation of the importance of efficiency.

Similarly, any force that brings the cost of farm machines down encourages farmers to adopt farm machines. For instance, improvements in manufacturing or marketing farm machinery, or even government subsidies or other financial aids, all result in cheaper and/or better machines.

Enforcement of nine-year compulsory education, as well as farmers' attitude toward higher education for their children, affects the agricultural labor supply and also the quality of such labor. Nine-year compulsory education postpones the age of entering the labor force by three years. Farmers' increasing desire for their children to have still higher education further decreases the labor supply. Now rural youth start to participate in field work later than their parents did. More than that, longer and higher education for rural youth makes them physically less muscular and technically less trained and less fitted to the traditional way of farming, which requires much physical strength like that possessed by their parents. All these things help make farmers seriously consider mechanizing their farm operations.

Machinery cost is composed of two parts, fixed cost and variable cost. Our earlier statements were directed to the fixed costs, such as initial investment, interest and depreciation charges. The more fully machines are utilized the lower these average fixed costs will be. Further research is desired to find ways to make a machine (like the power tiller) handle a wide range of farm operations instead of the one or two particular tasks for which it is primarily designed and used. That is, effort should be directed to machine attachments and other ways of enabling the machine to perform as many farm tasks as possible.

Operating (variable) cost of machines is not to be neglected, although fixed cost is a larger percentage of the total machine cost. Here, fuel, repairs, and maintenance are the major costs. In many countries, as a token of subsidizing farmers, the government regulates the price of oils for farm machinery at a special rate.

Farmers' access to a repair shop or service center is crucial, too. Since farmers, and hence the machines, are scattered around the rural area, quite often farmers have to travel a long distance to get broken machines fixed or for regular maintenance checks. Because of this, farmers are sometimes inclined to abandon broken machines.

Maintenance care, too, tends to be neglected. The seriousness of this problem becomes apparent when we consider that most farm operations have a time limit: farmers really cannot afford machine break-downs especially in an important stage of crop cultivation, nor can they afford to spend much scarce time for repairing and maintenance. If establishment of service centers scattered in the rural area is impossible, manufacturers should consider dispatching many service teams to go around during the busy season.

More basically, research should be strengthened to improve the quality of machines so that machine break-down may be kept at a minimum.

Forces causing labor shortage may be expected to prevail in any developing country. Ways of lowering the cost of farm machinery are greatly needed. The pace of spread of farm machinery depends greatly upon how far the farm machinery manufacturing industry develops and how far the government steps in to offer financial and other types of aids to the peasant farmers. Although both are equally important, government aid provides a short-cut in persuading farmers to adopt mechanization.

So much for the theoretical approach. Let us consider some of the practical use aspects of machinery that may hasten or retard adoption.

Unlike machinery used in manufacturing, farm machinery designed for field work should be light and easy to handle and move. Making machines light and easy to handle is a technical matter. Ease of movement is as much a problem of farm layout as a technical problem.

Farms in the old countries are notorious for their irregularity and fragmentation of plots of land and inadequacy or lack of farm lanes for transportation. In order to accelerate the mechanization process, the old-style farm layout must be re-organized. Here the land consolidation movement which has been enforced for more than a decade will prove to be a strong support for mechanization.

Machinery substitutes for human labor or cattle used in traditional farming. Thus it is natural that farmers compare the toil of operating machines in the field to the toil they experienced in the older days when they did the tasks by themselves or with cattle. Quickness is necessary for efficiency; so is lightness, compactness, and above all, convenience in machine operation. If we succeed in this respect, farming will cease to be unpleasant and tiresome; farmers will reap satisfaction from their farm business.

Climatic conditions also count, especially the season and duration of rainfall. Mechanization progresses more smoothly and quickly in an area where rainy days are few and do not coincide with the peak season of farm operations, when there is extraordinary demand for machine work.

Soil fertility and composition may also be influential in determining the pace of mechanization in a rural area. Since machinery is a substitute for human labor and cattle, it is expected that with the spread of farm mechanization the number of cattle will decrease. This has actually happened. Between 1960 and 1969, the number of power tillers increased by 11,300—from 3,200 to 14,500—while draft cattle decreased by 110,800—from 417,100 to 306,300.[2]

Cattle are an important source of organic fertilizers in soil. If farmers think that the maintenance of organic fertilizers on their farms may possibly become a problem after mechanizing farm operations, they will be reluctant to mechanize. In any case, farmers need to look for new sources of organic fertilizers in order to maintain land productivity after adopting mechanization.

Unfavorable conditions hindering farm mechanization

In the discussions above we examined the conditions favorable for farm mechanization, first from the theoretical, cost-returns viewpoint and then from the practical, machine-use viewpoint. It is understood that the opposite conditions will retard farm mechanization. Therefore, to avoid repetition, in this section we shall take up only those conditions that were not touched on above.

Farming, unlike commerce and manufacture, is characterized by considerable seasonal variation in labor demand. In the peak period, demand for labor is keen and strong, but the peak period occupies a very short part of the year. Farmers prepare and try to have in stock, if not enough labor force, certainly a large percentage of it, to meet the crucial peak-period labor demand.

The peak-period labor shortage may be severely felt, yet at other times the farm family may still possess a considerable amount of labor. If so, farmers will be reluctant to introduce machines unless they are sure that the other-than-peak-period labor situation will not be worsened. Without this assurance they may feel that the risk they bear is too heavy. Effective solutions are: (1) introduction of a farm family side-line business and (2) introduction of new farm enterprises to increase and spread out the over-all labor utilization throughout the year.

For some kinds of work, such farm machines as the present power tillers are not complete substitutes for traditional human labor or cattle. Complaints are often heard that power tillers cannot plow edges and corners of the field so well as the traditional way. This kind of complaint is reflected in farmers' practice of using power tillers to plow the land thoroughly first and then using cattle to finish up edges and corners of the field which were poorly done by the power tillers. So like any other substitute, machines cannot be expected to take over all stages of farm operations completely.

At the present level of machine quality, at any rate, many tasks still remain to be done (or finished up) by human labor and cattle. This involves over-investment in a sense: farmers who introduce machines on their farms are still not able to dispose of their cattle.

Standardization of farm machine parts and attachments is also urgently needed. At present, products of different farm machinery brands are not interchangeable, which causes farmers inconvenience and sacrifice. Action should be taken at once to correct this disorder, presumably by the government.

Fuel supply in rural areas is far from satisfactory, too. After stressing the importance of standardization of parts and attachments as well as the establishment of nation-wide authorized repair services—so-called appointed repair shops—for promoting farm mechanization, Peng observes that:

> "The fuel for power machines can be purchased from fuel stores at all the principal townships, but it is usually not clean enough and sold at a stiff price, thus affecting the service life of machines, especially the diesel engines. Though some township farmers' associations bought fuel in bulk to meet the need of the farmers, many farmers still prefer to purchase fuel on credit from the small fuel stores, thus losing in the end. How to supply cheap, clean fuel in sufficient quantities is indeed one of the important problems to be tackled before the program of farm mechanization can be stepped up."[3]

Sometimes the smallness of farms is cited as a hindrance to mechanization. There is no doubt that efficiency of farm machinery is positively correlated with the size of the plot of land. Thus farm mechanization in rice-growing countries is particularly handicapped because a plot of paddy field is rather small and enlargement of it is technically difficult.

To this one might add that in an old rice-growing country like

Table 1. Farmer Motivation for Acquiring Power Tillers (1965).

Response	Number of Households	Percentage
Efficiency of power tiller in plowing	146	47.4
Can do custom work for others	111	36.0
Can do transportation for others	40	13.0
To pump water	9	2.9
Need not keep cattle	2	0.7
TOTAL	308	100.0

Source: *Survey Report on Power Tiller Utilization in Taiwan*, Department of Agriculture and Forestry, Provincial Government of Taiwan (in Chinese), 1966, p. 5.

Note: Respondent could indicate only one motive.

ours, not only is the plot small, the farm is also small and, worse, it consists of many widely scattered, irregularly-shaped plots. Yet farmers' experience seems to suggest that this problem has not become serious.

Farmers with small-scale farms buy machinery with the expectation of increasing their cash income by performing custom machine work or transportation. In a 1965 survey of farmers' motivations for buying power tillers, custom work ranked second, followed by transportation service (Table 1). These two motivations together constituted 49 percent of the responses. In the early days of farm mechanization, when there were not many machines in rural areas, this expectation of opportunities for cash income could easily be fulfilled, but as mechanization progresses competition in custom work will become keener and acquisition of farm machines for this purpose may decrease.

Co-operative ownership or use of machines

Farm machinery is too much for small peasant farmers: it is rather expensive, and with their limited acreage the degree of machine utilization is so low that they cannot afford to invest in it. In order to overcome this difficulty, governments of countries with small farms often encourage co-operative ownership and utilization at least in the early stages of farm mechanization.

Three types of ownership and utilization can be distinguished.

The first type is private ownership and utilization by individual farmers. For the reason just stated, this can be economical only for farmers with large farms. Or in the transitory period when the machines have not yet become popular, small peasant farmers may successfully invest in machines by doing custom work for neighbor farmers and collecting cash income to pay off part of the cost.

The second type is joint ownership and utilization by (small) peasant farmers. The group may be neighbors, friends or relatives.

The last type is ownership by local government agencies or organizations like farmers' associations for the service of farmers in an area. Small to medium size machines like power tillers belong mostly to the second type, if not individually owned and used, while larger machines like tractors may be found in the third type.

With the second type—co-operative ownership of farm machines—problems arise in machine operation and maintenance. Farmers in this part of the world are not well trained in doing business cooperatively. If the group is rather small and the members are closely related to each other, it may be regarded as an extension of the family, so that joint ownership operates smoothly and the machinery is kept in good condition. However, in larger groups, conflict between members is more strongly felt, and annoyance grows.

Soon such a hopeless situation may develop that finally joint ownership is given up. Some members switch to individual ownership, while others find it convenient to rely on custom work. Thus the original economic merit that persuaded farmers to jointly own and utilize machines succumbs to economic and non-economic problems (mostly the latter) that emerge in actual joint operation and maintenance.

Ownership by farmers' associations for the service of member farmers fares no better. This business usually causes financial problems to the owner organizations. Operator problems are also hard to solve. Since it is not practical to employ operators for work that lasts only one or two months in a year, the associations usually assign their own staff members to operate the machines during the season, although they know that this, too, is not a solution.

The problem of making a time schedule is even more serious. Since every farmer wants machines to come to him at the right time, and this is obviously impossible, disappointment and complaint are inescapable. In addition, there is the weather problem. Sudden changes in weather may interrupt the time schedule. Further, the scattered location of the plots of land to be operated by the machines still remains a problem here, as in the case of individual or joint ownership.

In passing, it may be added that maintenance of machines under the latter two types of ownership is never as adequate as under the first type, individual ownership.

Thus neither type of co-operative ownership and/or utilization is likely to last long. Co-operative ownership and/or utilization must be deemed a transitory stage in the whole farm mechanization process. It is destined to collapse because farmers initially accept it only as a second best, a substitute for the best approach (individual ownership) which is not possible for them at the time. And in cooperative or joint use of machines, practical operational problems soon emerge to create conflicts. Thus the situation degenerates in a vicious cycle.

History seems to agree with this. Presently, co-operative ownership of farm machinery seems to have lost some of its attraction. To quote again from Peng:

> "At present, about 95 percent of the 21,153 power tillers in use are owned by individual farmers, and the rest owned by agricultural improvement stations, schools, farmers' associations, cooperatives, etc. This is true for the pumps, sprayers, dryers, etc. It proves that Taiwan farmers prefer to own their own machines, if they can afford to pay for them"[4].

Effect Motivation Links of Mechanization

Effects on factor combinations: labor intensity, land use, and machine utilization.

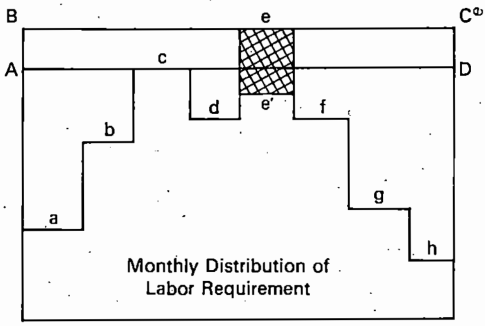
No matter how complicated the farmer motivation for mechanizing farm operations, one motivation always stands out clearly. Farm mechanization is always and primarily intended as a substitute for agricultural labor that has become scarce for various reasons, among which the increase in job opportunity outside of the agricultural sector is predominant. Hence it is obvious that mechanization must alter the factor combination on farms, or more broadly, the allocation of factors among different productive activities.

We shall take up labor first, for this is supposedly the factor most closely linked with mechanization.

Scarcity of labor is most concentrated in a short span of time. If machines are introduced to do tasks in this peak period, labor will be saved and the pressure will be somewhat reduced.

However, the reduction in the family's labor requirement is not just the amount saved in the peak period through direct substitution of machinery at that time. Additional labor is released because the maximum seasonal requirement is now lower (Figure 1). This is so because families maintain a stock of labor at or near to the level of peak-period load.

Fig. 1. Decrease of Idle Labor by Mechanization.



abcdefgh: Pre-mechanization labor requirement.

abcde'fgh: Post-mechanization Labor requirement.

Area: Amount of labor saved by mechanization.

Area ABCD: Amount of labor released by mechanization.

To use the labor thus released, farmers may try to intensify the labor input in other operations of the same enterprise, or they may allocate it to other farm enterprises, existing or newly introduced. Thus mechanization may temporarily decrease labor input in the crop that is mechanized, but the labor released will soon be put to use and the over-all labor intensity will finally be back to the original level, or nearly so.

The labor-saving effect will be accentuated if peak periods of two important farm enterprises originally coincided, so that with mechanization of one enterprise the labor saved can be reallocated to the other one, which will bring considerable additional income to the farmers.

Or finally, as often happens, with extra family labor available for outside jobs some farm family members may go out and find jobs in the non-agricultural sector, thus increasing the family's non-farm cash income.

In any event, it is unlikely that farmers will turn the saved labor into leisure. Somehow they will seek new outlets for it. Thus, the final outcome of mechanization as a labor-saving device is not likely to be more extensive cultivation. And it may result in an increase in family income.

How does mechanization affect land use? First of all, one of the major objects in mechanization is deep plowing. Peasant farmers expect machines to plow deeper than can be done by the traditional cattle.

Often this expectation has not been realized, due either to inadequate power of the machine, or to the kind of soil, or both. This is why peasant farmers prefer larger machines as their experience with mechanization accumulates. We shall take up this topic again in the replacement motivation section.

The degree of land utilization increases with mechanization. This is also a result of mechanization's labor-saving nature. With the newly released labor, a farmer may decide to bring new enterprises into his farm which he dared not do formerly because of excessive peaking of labor requirements. With mechanization the number of farm enterprises will increase as will the cropping index, which is a measure of degree of land utilization.

The degree of machine utilization directly determines the efficiency of investment. If the working hours of a machine are too short, returns hardly exceed the cost, and the machine turns out to be an over-investment. This danger is greater the smaller the farm.

Co-operative ownership and utilization of machines has been suggested, but that raises difficulties in other respects. Custom work is another way to overcome this difficulty. In fact, it is the way most commonly adopted by small peasant farmers. However, quite often they are so eager to pay off the initial investment cost in the shortest possible time that they operate the machines excessively and neglect machine maintenance and care, shortening the life of the machine (Table 2). Thus, in the final analysis, whether the machine pays off is rather questionable.

Just how much must a machine be utilized in order to pay off its cost? Or how large must a farm be to make a machine an economically sound investment?

Five hundred hours per year and five hectares of working area per power tiller have been suggested as the lower limits. Many calculations have been tried; none are perfect. The calculation must cover not only the direct changes in costs and returns but also the indirect derived changes in farm income or farm family income.

Table 2. Utilization of Power Tillers in Taiwan: Average Days of Use on the Owner's Farm and on Other Farms.

Unit: day

Size of farms (ha.)	Total	Work on own farm				Work on other farm				
		Sub-total	Plowing	Transporting	Pumping	Sub-total	Plowing	Transporting	Pumping	Other
Average	78.60	36.91	16.01	11.23	9.67	41.69	22.86	14.87	3.43	0.53
%	100.00	46.96	20.37	14.29	12.30	53.04	29.08	18.92	4.36	0.68
Under 1	98.40	12.67	3.41	6.40	2.86	85.73	29.24	49.72	6.77	–
%	100.00	12.88	3.47	6.50	2.91	87.12	29.71	50.53	6.88	–
1–2.5	75.60	27.36	9.28	10.64	7.44	48.24	29.12	14.63	3.07	1.42
%	100.00	36.19	12.28	14.07	9.84	63.81	38.52	19.35	4.06	1.88
2.5–5.0	70.41	37.58	16.49	10.39	10.70	32.83	20.87	9.30	2.66	–
%	100.00	53.37	23.42	14.75	15.20	46.63	29.64	13.21	3.78	–
Over 5	88.94	66.46	34.57	16.26	15.63	22.48	11.02	7.65	3.81	–
%	100.00	74.72	38.87	18.28	17.57	25.28	12.39	8.60	4.29	–

Source: *Tien-song Peng, The Development of Mechanized Rice Culture in Taiwan,* JCRR, PID-C-327, June 1969, p. 22.

From the broad, over-all viewpoint, if we want to make the coverage of calculation wide enough, the balance-sheet approach must be tried rather than the usual, simplified cost analysis. As we all know, mechanization means a fundamental change in farm management. Its influence is deep as well as wide. Therefore, any simplified method of calculations is bound to miss some items. Only the balance-sheet approach, that takes every aspect of both costs and returns into account, can catch the whole picture.

Effects on enterprise combinations

By nature, the first and foremost purpose of mechanization is labor saving, to reduce the peak-period labor load. As we have seen before, farmers are unlikely to turn the labor thus saved into leisure. They will presumably seek outlets for this labor.

Among many possible ways to use released labor, one common way is to introduce new enterprises to the farm. These enterprises should supplement the existing enterprises in labor use and should also have high labor-absorbing capacity. Mushroom production as well as livestock and poultry raising may be cited. These enterprises also provide much-needed organic fertilizers.

This last point brings us to a new dimension in enterprise combinations. After mechanization, due to the decrease in self-supply of organic fertilizers, maintenance of land productivity becomes a more serious problem. Being aware of this, farmers may introduce enterprises like those mentioned above or they may make a fundamental change in cropping system, allowing more acreage for green manure, fallow, etc., to balance and maintain the land fertility.

Thus mechanization may lead farmers to more diversified farming. As their businesses become diversified, labor shortage will again be felt, and this will act as a second-round motivation to simplify farm operations. From then on, they will be really on the track towards a high degree of mechanization.

Farmers may, alternatively, find outside jobs in the non-agricultural sector for their released labor. Mechanization in this case changes their status from full-time to part-time farmers, deriving incomes from both agriculture and non-agriculture.

Their reliance on the non-agricultural sector as a source of living may even come to predominate, so that farming becomes a side-line and they try to minimize the amount of labor devoted to it. Here, again, motivation for further mechanizing farm operations arises. (Another solution may be to organize a co-operative farming group. Farmers take part in decision making but leave the actual work to be done by hired laborers or machine services).

Toward a more mechanically-oriented way of farming

Farm mechanization in Taiwan, and in Japan, too, for that matter, is different from that in the United States. Farming in the United States has been built up with the development of machinery as a central force. The history of U.S. agriculture is the history of farm machinery, a process of mechanization of the entire farming framework. Ours is different: machines are adopted for particular farm operations, but the core of traditional farming still remains.

Mechanization here stops short of remodeling the whole system of farming. Basic features of the farming are not affected; only those farm operations to which machines are applied show changes. In other words, our way of farming is still basically human-labor-oriented, with one or two farm operations done by machines, and not co-ordinated into but independent of other stages of the entire series of tasks.

If farm mechanization continues in this manner, the effect on efficiency and on costs and returns will be limited. At some point in the mechanization process this heterogeneity in which most farm tasks are performed by human labor and cattle and only a few by machines will be recognized as retarding further progress. Ultimately we will face the necessity of re-building our whole farm operation scheme on a new basis. We must move toward a mechanically-oriented way of farming.

One retarding factor may be the inflexible design of the farm machines so far introduced. Take the power tiller as an example. The farm tasks it is primarily intended for are very few, although they are centered in the period of peak labor requirement and thus contribute greatly to the lightening of labor pressure. Emphasis should be put on the design of machines that are flexible enough to perform a wide range of farm tasks in order really to mechanize our way of farming.

We in Taiwan have just started a pilot project in two or three rural areas. The foremost feature of this project is all-mechanized farming: not only is each task mechanized, but also mechanization of tasks is carefully co-ordinated to make the entire farming operation a unity, not just a collection of mutually independent mechanized operations. This project is now being closely observed. We hope it will open a new dimension for farming in Taiwan.

Some problems must be carefully considered before shifting from traditional man-labor and cattle farming to modern mechanized farming. For instance:

(1) One characteristic of traditional farming is the continous crop system (the system of growing the same crop continously). Should this system be changed into a crop rotation system, preferably including pasture and fallow?

(2) Traditional rice growing requires transplanting. In changing to modern mechanized farming, the choice between transplanting and direct seeding should be carefully considered. One drawback of the latter is the problem of weeding.

(3) There is also a problem of fragmentation of land. Modern mechanized farming will bring larger and larger machines to the farm. The original irregularly shaped, small plots of land must be re-organized into modern, large plots to facilitate large-machine operations. The difficult problem of how to modernize out-of-date farm layout conditions to accomodate modern mechanized farming must somehow be solved.

(4) How will the yield, intensity of cultivation, etc., be affected by the change? We all too easily associate mechanization with more extensive cultivation and lower yield per unit of land as compared with the traditional man-labor and cattle farming. However, this comparison between the two different ways of farming is usually made between two different countries at the same time. The comparison we must make is of yield and intensity changes with different ways of farming in the same country.

For our comparison, it seems safe to say that modern mechanization need not cause either the yield or the intensity of cultivation to decline. At least there is no clear-cut evidence that these results will occur.

Replacement motivation

The physical life of present power tillers has been estimated to be from 7 to 9 years, but the actual replacement age, according to various surveys, has been around 5 years.

Every mechanized farmer must face the replacement problem. He must somehow decide (1) when to replace, (2) how to replace, and (3) with what type of machine to replace his present machine.

Decisions regarding replacement are influenced by (1) the degree of machine utilization by farmers, (2) the pace of improvement in the quality of machines, and (3) sales promotion by machinery dealers. Small farmers who rely on income from working for others for paying off the initial investment tend to use machines excessively and thus to shorten the machine life. Type of ownership and use is also influential: machines owned and used jointly and those owned by organizations tend to have shorter life than those individually owned and used. Under joint ownership and use, maintenance care is bound to be inadequate.

In the early days of farm mechanization, quality of machines improved rapidly from year to year, so that old-type machines easily became economically obsolete. The change from iron wheels to tires on power tillers, and from the rotary type to the tractive type, are just two examples.

Power also counts. Farmers usually bought small-power tillers initially, and were quick to wish that they had bought more powerful ones.

As the farm machinery industry develops, the type and quality of machines may become standardized. (The law of diminishing returns operates in the pace of quality improvement). Power, too, may become larger and larger, but at a declining rate, so that the replacement requirement will be stronger in the early days but will eventually fade away as the machine industry develops.

We have seen that farmers soon desire to acquire larger and better machines, for these machines are more powerful and efficient. However, as efficiency grows, the volume of work done in a day increases. The situation may develop into a stage where the farmer who works behind the power tiller on foot becomes exhausted long before the power tiller reaches its work capacity. This reason, too, may motivate farmers to replace the old walking tillers with new riding tractors.

Finally, active sales promotion by local manufacturers and dealers also influences replacement decision making.

This last point leads us to the second problem, how to replace. Since the physical life of power tillers is longer than the present economic obsolescence age, disposal of one's present old tiller becomes a crucial problem. Many dealers, in order to expand their sales, accept "trade-in" contracts. In this case the farmer pays a "net" amount but does not know the exact price he is paying for the new machine and the amount he is receiving as trade-in value for the old one.

When replacing their old machines, farmers at present prefer (1) machines with higher horsepowers (2) new types or models, and (3) machines with seats to ride on. That is, there is a strong tendency towards larger power tillers and, to some extent, towards tractors. In a recent survey, more than 70 percent of power tiller owners stated that they wanted to buy larger machines next time, while less than 7 percent said they wanted to buy smaller ones.[5]

As a final note on replacement, in Europe and in the U.S. replacement has been found to be closely related to the business cycle. Here this kind of relationship has not yet been found, but in the future it will certainly emerge.

Non-Managerial Farmer Motivation for Mechanization

Since farm mechanization means changes in the way of agricultural production, major concerns in deciding whether to mechanize or not center around the farm management point of view. Yet farmer motivation for mechanization is complex. In addition to the efficiency criterion, there may be other, non-managerial motivations that persuade farmers to adopt machines. Only a few rather outstanding non-managerial motivations are listed here.

First, some farmers have decided to mechanize largely because of persuasion by influential persons in their circle who were much in favor of mechanization. These persons may be the farmers' relatives or friends or leaders in the area. If village leaders are very active in this "education and extension" role, then mechanization proceeds rapidly in that area. One of our more highly mechanized areas owes much to this sort of leadership for its farm mechanization.

Secondly, mechanization spreads more rapidly in one area that in another because of unevenness of salesmen's activities among areas. For instance, farmers in areas close to machinery manufacturing plants are better located for buying machines. Again, for various personal reasons, each salesman or dealer has his own area of specialization. Sales promotion is more active in some areas, and where it is emphasized there is more mechanization.

The world becomes smaller and smaller. The horizons of our activity and knowledge retreat farther and farther. The demonstration effect nowadays exercises more and more influence over our actions. A "keep up with the Joneses" attitude among farmers accelerates the pace of mechanization once the process is underway. This is why farm machines are said to possess a "consumers' goods" nature, too.

Finally, there are farmers whose motivation for farm mechanization includes, among other things, a desire to attract heirs to remain on the farm. As we noted earlier, today's youth is physically less muscular and technically less equipped for the traditional farm field work, which is overwhelmingly muscular. Worse, in comparison to work in the non-agricultural sector, farm field work is notoriously arduous and offers a much less attractive environment.

It is often heard that the out-flow of agricultural labor has been so great that the farm labor supply has almost reached bottom. The younger farm workers, especially, have moved out in such numbers that now only the older generation remain on the farms, posing a new problem of who will succeed to these farms when the aged pass away. It is human and natural that parents want sons to follow them in their occupation. Farm mechanization is one such means to keep the younger generation interested in farming.

Summary

Drawing upon both theoretical and historical backgrounds, we have examined in detail farmers' motivations for mechanization.

We have seen that an unlimited supply of agricultural labor helped to develop the widespread tenancy system. It is only since industrialization has absorbed a considerable amount of farm labor, and since the recent land reform, that farm mechanization has actually become possible. There had to be a labor shortage that made farmers, for the first time, aware that labor costs money.

Farm mechanization involves complicated decision making. Beyond farmers' discovery that labor costs money, no single motive can claim sole responsibility for driving farmers into mechanizing farm operations. The major motivations are economic, but some are non-economic. Some major items that farmers consider in mechanization are, on the one side, the price, quality, and utilization range of the machine and the quality of its performance of farm tasks; and on the other side, wage rates, job opportunities, and differences in working environment.

To the peasant, machinery cost is sometimes a rather heavy burden. Therefore, besides individual ownership and use, there has been joint ownership and use by small groups of farmers, and collective ownership by organizations like farmers' associations, with co-operative use by member farmers. Farmers definitely prefer the first type, but the latter two should not be disregarded. Further research on economic management of machine use under the latter two ownership arrangements is certainly to be encouraged.

Over-all agrarian conditions in the countries of the Far East are admittedly not suited to farm mechanization, but this does not prevent farm mechanization here. It is our belief that somehow we can develop the type of machines that can be successfully applied within our agrarian framework. Japan provides us with a hopeful example at this point.

The current trend of farm mechanization is a piece-work approach, mechanizing only a few tasks, piece by piece, and keeping the whole system of farming as it is. As mechanization proceeds, we may come to consider the present way of farming an obstacle to further increase in efficiency. Research is needed to understand the long-run process of mechanization and its effects on the whole framework of farm management. Not only must inputs be re-combined; the crop system, the combination of enterprises, all will undergo changes to fit the ever-intensifying mechanization process.

This study has doubtless omitted some facets of farmer motivation for mechanization. However, it is hoped that the major aspects have been presented. Yet this world is changing and so is the pace of mechanization and its effects on management and farmers' economic welfare. Facing this ever-changing world, it is the author's wish that we do not lose interest in nor discontinue research for modern mechanized farming that will contribute to the peasants' welfare.

[1] Kudo, Zyuro, *Farm Mechanization Problems in Taiwan*, JCRR, Taipei, 1970, pp. 6, 8 (in Chinese).

[2] These and other statistics on equipment numbers cited in this report are for the most part taken from the *Taiwan Agricultural Yearbook*, 1969 edn. They will be more conservative than various other estimates, in part because they include only machines currently in use, not the larger cumulative total of all machines of the particular type that have been sold.

[3] Peng, Tien-song, *The Development of Mechanized Rice Culture in Taiwan*, JCRR PID-C-327, June 1969, p. 34.

[4] Peng, Tien-song, *op. cit.*, p. 22.

[5] Peng, Tien-song, "A Survey on the Utilization of Power Tillers and Mist-blowers in Taiwan", *Journal of Chinese Agricultural Engineering*, V. 16, Nos. 1 & 2, June 1970, p. 3 (in Chinese).

CURRENT PROBLEMS OF FARM MANAGEMENT ON MECHANIZED FARMS

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The farmers of Taiwan today face a number of problems arising from the impact of rapid industrial development in recent years. The increasing cost of labor, in addition to the high cost of such input factors as chemical fertilizer and pesticides, has lowered the profit of farm production and widened the disparity between farm and non-farm income. Therefore, the younger generation are leaving the farms, the agricultural labor force is decreasing, and agricultural capital is flowing out to the non-agricultural sector.

Obviously, Taiwan is experiencing an important agricultural structural transformation. At this critical stage, the problem of how to improve farm management in order to increase farm income and to modernize farming has been emphasized by Government authorities. Farm mechanization is one of the things vitally needed both to increase agricultural production and to improve farming efficiency in Taiwan.

Change in the relationship between labor and capital in production is of great concern to economists as well as to politicians and administrators. Mechanization of farming in developing countries affects the whole economic and social structure. It changes primitive and self-sufficient agriculture into complex, more specialized and commercialized agriculture, which depends less on human labor and natural resources.

Farm mechanization, in this regard, has advantages, but it also involves problems.

During the last two decades, as the total number of farm families and the average number of persons per farm in Taiwan increased, the average farm size and per capita cultivated land area decreased.

These trends forced farmers to adopt more intensive farming systems with increasing animal production, on the one hand, and on the other to push out surplus farm labor to earn extra off-farm income whenever possible. The low level of wages led to use of more labor on the limited farm land, and also contributed to capital accumulation in industries and other non-agricultural sectors.

Since 1965, after three successive economic development plans, the Taiwan economy has turned to another phase of development. The mobilization of rural labor has been accelerated by the wide disparity of income between farm and non-farm labor. The situation of agriculture has changed markedly as a result of of rapid development of industry. Facing the need to transform the agricultural structure, the farmer in Taiwan now seeks to earn a living by using more capital instead of "earning his bread by the sweat of his brow". The traditional labor-intensive farming methods and cultural practices are being re-examined by agriculturists and farmers.

Extension of Farm Mechanization

Situation of Taiwan farms

Because of the rapid increase of population in Taiwan and the scarcity of cultivated land, the cultivated area per farm has become smaller and smaller. The average cultivated land area per farm decreased from 2.00 hectares in 1925–40 to 1.03 hectares in 1969, with an average size of farm family of seven persons. Moreover, some surburban cultivated lands have been transferred to non-agricultural uses due to the splendid progress in commerce and industry. According to the agricultural census of 1965, about 90 percent of all farm households had less than 2 ha. of cultivated land, and only 10 percent had more than 2.0 ha. (Table 1).

The progress of agriculture has been achieved chiefly through greater labor input, larger capital investment in irrigation facilities, use of chemical fertilizer, control of pests and diseases, and adoption of proper cultural practices on the limited area of cultivated land. However, with the gradual transfer of farm labor to urban areas, the rural labor force is now declining. The number of draft cattle is also being reduced.

It is clear that the expansion of cultivated land in Taiwan is

Table 1. Distribution of Farm Households by Size of Farm in Taiwan, 1965.

Farm size	No. of farm households	Percent	Cumulative percent
Under 0.5 ha.	318,260	37.9	37.9
0.5–1.0	241,800	28.8	66.7
1.0–2.0	194,040	23.1	89.8
2.0–3.0	55,520	6.6	96.4
3.0–5.0	25,160	3.0	99.4
above 5.0	5,500	0.6	100.0
Total	840,280	100.0	

difficult, and that a noticeable decrease of agricultural population cannot be expected in the short run. Therefore, fragmentation of cultivated land will continue to be a problem unless government can enact some law to restrain fragmentation.

The development of industry has increased the number of part-time farmers. However, the part-time farmers lack the enthusiasm to make new trials or to improve farm management. Incomes per unit of land of these farmers are lower than average because of failure to perform farm operations on time, improper management, inefficient use of farm labor, use of less production inputs or improper use of them, etc. These factors, in turn, obstruct future agricultural development and impede the progress of agricultural modernization.

General factors motivating farm mechanization

The benefits from introducing any type of farm machinery on farms can be classified as labor-saving effects and production effects. Generally speaking, the farmers who operate the larger farms assess the cost reduction through time and labor saving by the probable increase in the real wage rate in farm operation and by the saving of losses in production that would probably result from delays in performing operations without machinery.

Low purchasing power and fragmentation of land are the major factors limiting the application of efficient tools on small farms. Use of modern machinery only on an individual farm is too costly

Table 2. Comparison Between Changes in Numbers of Power Tillers and of Draft Cattle, 1956–69.

	1955–57	1957–59	1959–61	1961–63	1963–65	1965–67	1967–69
Changes in numbers of power tillers (A)	+171	+2,082	+3,051	+3,766	+3,134	+5,027	+7,400
Changes in number of head of draft cattle (B)	+328	+4,813	−2,951	−24,760	−19,078	−32,492	−32,641
Ratio $\frac{B}{A}$	+2	+2	−1	−8	−6	−6	−4

and impractical. However, small farmers can use machines mainly for outside jobs to earn income to support their families.

Application of power machines on farms in Taiwan started first on farms that were relatively large and more specialized and commercialized. Their economic status was more favorable, and they were more receptive to new methods. In addition, the new practice of farming with machinery was both applied and extended by small farmers who did custom work. They usually obtained the new but expensive machines through loans from financial organizations. Thus, the machines have been adopted rapidly on the relatively larger farms, and are used widely by smaller farms through custom work. Needless to say, the experiment stations of agricultural agencies have played an important role in demonstrating farming practices using the new machinery so as to accelerate the adoption of new farming methods by all farmers.

Power farm machines are used on Taiwan farms mainly for land preparation, water pumping, pest control, and transportation of products. Small numbers of rice transplanting, harvesting, and grain drying machines are also being used. Up to the present, mechanization of land preparation has become well established by the wide use of power tillers, mostly in paddy fields. As shown in Table 2, for every power tiller added since 1963 four to eight head of cattle have been displaced.

During the past ten years, power machinery has spread to some extent, and the machines have become bigger and better. The

Table 3. Number of Households and of Hectares of Cultivated Land per Power Tiller, and Power of Tillers, Taiwan, 1956–69.

	1956	1958	1960	1962	1964	1966	1968	1969
Number of households per power tiller	12,439	1,283	212	108	82	60	41	36
Hectares of cultivated land per power tiller	14,597	1,472	234	116	86	63	43	37
Percentage of power tillers above 8 HP	–	–	27	28	31	36	53	58

price of machines per unit of horse power has decreased. This has stimulated custom workers to replace obsolete machines quickly. Farm work has been made more efficient and pleasanter.

In Taiwan, the power tiller is still the backbone of farm mechanization. The total number of power tillers in Taiwan reached 24,640 in 1969. This was approximately one power tiller for every 36 farm households or every 37 hectares of cultivated land. The changes in these ratios and in the horsepower of tillers in recent years are shown in Table 3.

A case of farm mechanization in Erhlun township, Central Rice Region

Erhlun township is located in the central double rice crop region, a part of Yunlin Prefecture. There are 5,000 farm families and 4,200 hectares of cultivated land with good irrigation facilities. Power tillers have been widely used in this township. There was approximately one power tiller for every 10 households or every seven hectares of cultivated land in 1970. The writer spent several days in this township interviewing farmers who own power tillers. Table 4 indicates the change in numbers of farm machinery in the past ten years.

Based on interviews, the relative importance of factors motivating these farmers to introduce power tillers is summarized in Table 5.

The versatility of the power tiller makes it not only efficient in farm work and in transportation but also useful for irrigation work such as pumping water. These advantages can protect farms from drought damage and help them maintain production.

Deeper plowing, increase in wage rates, and difficulty in hiring farm labor were secondary reasons for introducing power tillers in this area, and recommendation by salesmen was a minor reason.

Farmer's Attitude and Problems in Farm Mechanization

For technical reasons, the power tiller is the major modern farm machine in Taiwan. Machines for transplanting and harvesting, activities that generally consume a large amount of human labor, are still in the experimental stage. Some operations, such as leveling of paddy fields, are still done by animal power with

Table 4. Trend of Extension of Power Farm Machinery in Erhlun Township.

	1960	1962	1964	1966	1968	1969	1970
Power tillers:							
Number of households per machine	101	32	24	18	13	11	10
Hectares of cultivated area per machine	92	29	20	15	11	9	7
Power water pump:							
Number of households per machine	186	8	6	3	3	3	
Hectares of cultivated area per machine	170	7	5	3	2	2	

Note: The droughts in 1961 and 1966 accelerated the extension of power machines in this area.

Table 5. Factors Motivating Farmers to Introduce Power Tillers on Farms in Erhlun Township.

Reason	Number of farmers in sample mentioning reason*
1. Higher efficiency of work within proper time	15
2. For custom work after completing of work on farm	10
3. For deeper plowing	7
4. Increasing wage rate in the area	6
5. Difficulty in hiring labor or custom work	6
6. Prevalence of power tillers in the area (demonstration effect)	6
7. Recommendation of salesman	3

* Fifteen sample farms visited in May 1971.

traditional tools. This shows the need both for new attachments adapted to local conditions and for modification of cultural methods or improvements in crop varieties so as to increase production efficiency on farms.

Use of herbicides in rice production is a case of substitution of capital for labor. The application of herbicide will save about 270 hours of labor per hectare, about one fourth of the total labor input in rice production. However, on small farms the cost of herbicides places them at a disadvantage compared to weeding by family labor, and lack of technique of application also has limited the use of herbicides by general farmers.

Based on the sample survey in Erhlun township, farmers' attitudes toward mechanization may be summarized as follows:

1. The prices of power machines and interest rates on loans from financial organizations are considered too high by all the farmers. Therefore, most private farmers find the burden of owning power machines beyond their financial abilities.

2. Small farmers who own power tillers have had enough additional income from custom work to cover not only the interest on loans obtained from financial organizations but also a part of the cost of the machine. However, due to the increase in numbers of machines, the competition for custom work has become strong making it less profitable. Some owners expect to replace their power tillers with bigger or more efficient machines so as to compete more profitably.

3. Large farmers usually buy a power tiller just for their own use. Three or four medium-size farms with a total area of five or six hectares of farm land often join together to buy a power tiller for joint operation.

4. Farmers in Erhlun township who do not own power tillers state that they can hire machine work whenever they want, and do not intend to buy machines themselves.

5. For other machines such as rice transplanters or harvesting machines, there is little or no demand among farmers in Erhlun township, where power tillers are already widely owned. This may be attributed to financial disability, high interest rates, small size of farms, or lack of technical know-how.

6. The after-service rendered by machine makers is still considered insufficient. Costs for spare parts and repairs are high

relative to those in the township agricultural mechanization promotion centre.

7. All the farmers who own power tillers wish that more technicians could be employed in the township agricultural mechanization promotion centre and that more spare parts could be made available. The costs of repairing rendered by the centre are considered reasonable.

8. Changes in models, increase in horsepower, and improvement in the design of farm machines are relatively fast. This makes after-service more difficult because of lack of spare parts. Furthermore, it tends to accelerate machine depreciation and thereby increases the cost of operation.

9. Higher yields of rice and more production in the summer and winter seasons are closely associated with mechanized farming. These are results of high capitalization which usually involves mechanization of cultural practices.

Intensification of Land Utilization

Decreasing trend of cropping index

On the limited acreage of irrigated arable land four crops a year are generally grown, two major rice crops and two intercrops. The total annual growing days of all the crops exceeds 365 because of use of the inter-relay planting technique.

In order to maintain the fertility of the soil, farmers in Taiwan use much chemical fertilizer as well as organic fertilizer. The refuse from livestock is never wasted. The winter sweet potato crop is usually the major feed for hog production. The foremost reason why most farmers keep hogs is, indeed, to collect refuse for fertilization of crop production. Livestock is in general an important integral part of the whole farming system in Taiwan.

In the past, most small farmers have used intensified and diversified cropping systems without much use of power machinery. However, the economic transformation and the increase in wages of farm labor have changed the traditional farming system with intensive utilization of labor. With the shortage of farm labor, the work of land preparation, pest control, fertilization, harvesting, etc., cannot be completed fast enough.

The recent decrease in the cropping index in Taiwan (Table 6), particularly in the winter crop area, is the combined result of increasing labor cost and capital input factors.

Table 6. Changes of Multiple Cropping Index in Taiwan.

Year	1953	1955	1957	1959	1961	1963	1965	1967	1969
Index	173	171	179	182	186	185	189	187	184

Source; Provincial Department of Agriculture and Forestry (PDAF)

A case of cropping system adjustment and its method

The farming system in Taiwan is centered on rice. Farmers have adopted intensive farming methods to keep family labor fully engaged for increasing the family income. The intensive farming systems with great labor consumption require the replacement of labor with labor-saving farm machinery for further increase in farm productivity.

The introduction of power machines enables farmers to maintain intensive farming systems and increase the cropping index, because farmers can do field operations much more quickly and widely and better than in the conventional way. Furthermore, the area of such commercial crops as melons and vegetables, grown after the first rice and before transplanting the second rice crop, has greatly increased.

The area of winter crops has decreased in recent years, due mainly to unfavorable income from them. Therefore, they are gradually being replaced by green manure crops for maintaining land fertility. But the area of summer crops, especially melons, has increased in Erhlun township as a source of cash income to farmers.

Before harvesting of the 1st crop, melons and vegetables are planted in the same field. After the summer crop is harvested, land has to be prepared promptly for transplanting the second crop. Again, in the fall, sweet potatoes are planted between the rice rows before harvesting the second rice crop, or vegetables are planted immediately after the second rice harvest. The adoption of power tillers has made it possible to prepare the fields within a very short time and thus has made it more feasible to maintain the intensive cropping system.

Table 7. Cropping Methods Applying on Power Tiller Owner Farms in Erhlun Township.

Case farms	Operating area	Cropping area by season (ha.)					
		1st crop	Summer crop	2nd crop	Winter crop	Total	Cropping index
1.	1.8	R. 1.8	M. 0.2	R. 1.8	G. 1.8	3.8*	211
2.	2.2	R. 2.0	—	R. 2.0	V. 0.2 S. 0.3	4.7**	214
3.	2.0	R. 2.0	M. 0.5	R. 1.6 S. 0.4	S. 0.2 V. 0.5	5.2	260
4.	1.3	R. 1.3	M. 1.3	R. 1.3	—	3.9	300

Notes: R. = Rice
M. = Melon
S. = Sweet potatoes
C. = Green manure
V. = Vegetable
* Excluding the acreage of green manure crop
** Including 0.2 hectare of orchard

9/13-pts

Changes of Wage Rate and Labor Utilization

Changes of labor distribution and utilization of farm machines

In farm mechanization, machines replace or substitute for human labor and animal power. However, many families who own a power tiller still retain their draft cattle. The main reasons are: (1) the farm roads are too narrow or are fully planted with subsidiary crops; (2) the power tiller is especially efficient for plowing, but is less efficient than draft cattle in leveling; (3) cattle can plow areas in small fields that the machine leaves unplowed; (4) cattle can transport fertilizer or products to or from wet fields; and (5) in case of trouble with the machine, some field work can be done by cattle.

Power machines have enabled farmers to increase their crop area and further enlarge their farm operation, because high-capacity machines help get farm work done at the proper time. Therefore, the potential saving of labor cost is limited, because farmers are using their resources more efficiently and intensively. Table 8 shows the difference in labor input on farms of power tiller owners and general farms in the Central Rice Region of Taiwan.

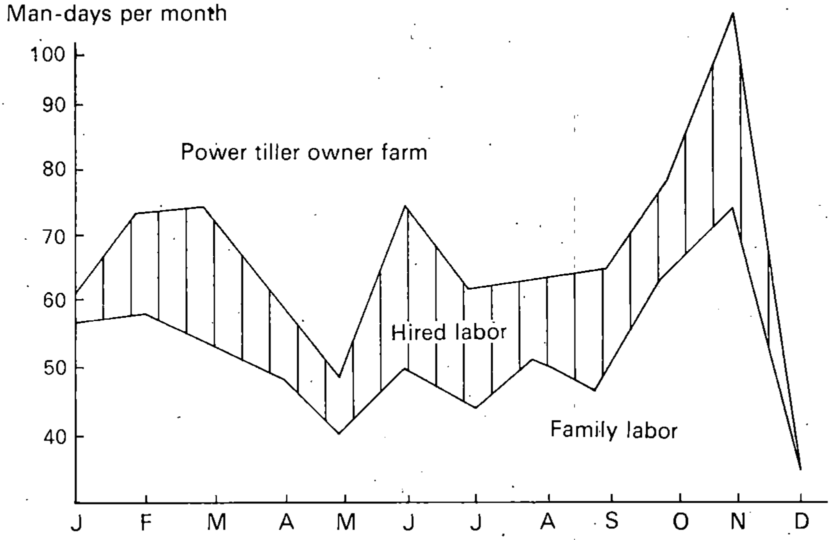
Better timing of operations and better performance using power machines both contribute to higher yields for various crops. In addition, more efficient use of inputs such as compost manure, chemical fertilizer, and pesticides may improve the quality and increase the quantity of the product.

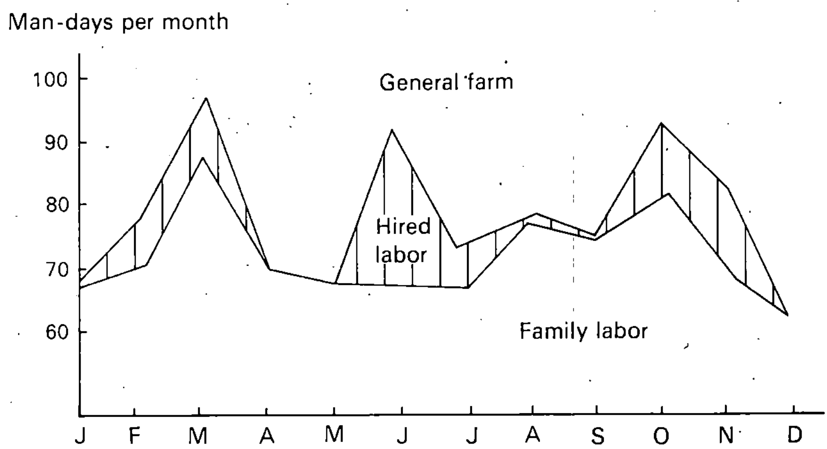
Farmers in Taiwan usually have three or four peak seasons of labor requirement within a year. In harvesting and land preparation, planting, and transplanting, the work must be done within a short period. Figure 1 shows the seasonal labor distribution on farms of power tiller owners and general farms in the Central Rice Region of Taiwan.

Changes of wage rate and extension of custom work in Erhlun township

In the past several years the wages of farm labor have increased considerably. This influences the cost of agricultural production and gives way to the custom work of machines. Table 9 compares labor wages for land preparation and charges per hectare for custom plowing by a power tiller in Erhlun township.

Fig. 1. Seasonal Labor Distribution on Farms of Power Tiller Owners and on General Farms in the Central Rice Region of Taiwan.





Source: Survey Report on the Utilization of Farm Machinery. Taiwan Provincial Department of Agriculture and Forestry, Dec. 1968.

Table 8. Comparison of Labor Inputs on Farms of Power Tiller Owners and General Farms in Central Rice Region of Taiwan.

(Unit: working days)

	Total labor input			Labor input per hectare		
	Family labor	Hired labor	Total	Family labor	Hired labor	Total
Power tiller owner farms (A)	633.6	180.2	813.8	481.8	137.0	618.8
General farms (B)	878.2	70.0	948.2	585.4	46.7	632.1
Comparison (A−B)	−244.6	+110.2	−134.4	−103.6	+90.3	−13.3

Notes: The average cultivated areas of power tiller owner farms and general farms are 1.315 and 1.50 hectares, respectively.
The power tiller owner farms saved 134.4 labor days by 212.5 hours of power tiller work. In general, the wage rate is extremely high for plowing and harvesting work.

Source: Survey report on the utilization of farm machinery, Taiwan Provincial Department of Agriculture and Forestry, Dec. 1968.

The labor exchange system prevailing in the busy farming season is a primitive form of cooperation in rural Taiwan. Some farmers who have purchased farm machines jointly for cooperative use have found it profitable to do work for hire for other neighbors after completion of their own farm operations. Some machines are apt to be overworked during the busy farming seasons.

When the number of farm machines increases in an area, machine owners compete for custom work. Both the unit charge for custom work and total area of work may tend to become less and less. Some machine owners, therefore, are apt to use their machines as many hours as possible during the farming season. However, the total area of custom work will decrease as the machine becomes obsolete. Some case studies in Erhlun township show the diminishing trend of custom work due to the obsolescence of machines and the increase in number of machines. This is shown in the Table 10.

Table 9. Changes of Wage Rate and Charge for Custom Work in Erhlun Township.

Year	Wage for plowing by man with cow		Charge for custom plowing		Relative index
	NT$/day	Index (A)	NT$/chia**	Index (B)	($\frac{B}{A}$ × 100)
1961–62	80	100	800	100	100
1963–65	90	113	800	100	88
1966–67	100	125	800	100	80
1968	110	138	900	113	82
1969–70	120	150	1,000	125	83
1971	140	175	1,000	125	71

* Plowing twice without leveling.

** One chia equivalent to 0.96992 hectare.

Table 10. Area of Custom Work by Sample Machine Owners in Erhlun Township.

Unit: hectare

Year	Cultivated land per power tiller in the township	Total area of custom work by sample machine owners		
		Owner A	Owner B	Owner C
1962	29	16	8	–
1963	23	15	24	–
1964	20	15	24	–
1965	17	19	20	–
1966	15	20	14	–
1967	13	15	2	–
1968	11	8	6*	7
1969	9	2	6	15
1970	7	–	6	15

* Purchased a new machine

The average annual use of power tillers in Erhlun township was 746 hours, 117 hours more than the average found in the JCRR survey of the utilization of power tillers in 1969. The total hours of use may be affected by size of farm, density of machines, soil structure, irrigation facilities, and cropping pattern, as well as by social and economic factors.

All the cultivated land in Erhlun township has been consolidated. Therefore, a power tiller can easily be moved from place to place for pumping ground water in the dry season. The annual use of a power tiller will vary with the amount of pumping work (Table 11).

Timely plowing and irrigation have enabled tiller owners to increase yields above the level when they depended on custom work for plowing. The yield of rice obtained by power tiller owners is 12 to 19 percent higher than that of farmers who do not own power tillers.

Changes of labor efficiencies

Based on the report of the survey on utilization of farm machinery, the family labor and total labor inputs on farms of power-tiller owners have decreased by 27.9 and 14.2 percent, respectively. Hence the machine owners have employed more hired labor to do their ordinary farm work, enabling family members to do outside work and earn off-farm income. Their

Table 11. Utilization of Power Tiller On and Off Owner's Farm in Erhlun Township.

(Unit: hours)

	On farm			Off farm		Total
	Plowing	Pumping	Other	Plowing	Other	
For 1st crop	30	60	5	225	1	321
For 2nd crop	30	45	5	200	1	281
For summer or winter crops	16	90	6	30	2	144
Total	76	195	16	455	4	746
% distribution	10.2	26.1	2.2	61.0	0.5	100

Table 12. Labor Efficiency on Farms of Power Tillers Owners and on General Farms in the Central Rice Region, 1966.

Items	Average of power tiller owner farms (A)	Average of general farms (B)	Comparison (A − B)	Comparison Index $(\frac{A}{B}\times 100)$
Labor inputs on farm:				
Family labor (days)	633.2	878.2	−245.0	−27.9
Total labor (days)	813.8	948.2	−134.4	−14.2
Farm economy:				
Farm receipts	94,733	89,540	+5,193	+5.8
Farm income	46,584	47,540	−956	−2.0
Labor productivity:				
Farm receipts per day for total labor input on farm	116	94	+22	+23.4
Farm income per day for family labor input on farm	73	54	+19	+35.2
Physical input and rice output per year (2 rice crops) per ha.:				
Labor input (days)	285	268	+17	+6.3
Hours of machine use	116	—	+116	
Animal labor (days)	—	26	−26	
Yield, paddy (kg)	10,471	9,462	+1,009	+10.6

Source: Survey report on the utilization of farm machinery, Taiwan Provincial Department of Agriculture and Forestry, Dec. 1968.

Table 13. Price of Power Tiller, Amounts of Subsidy and Loans Made by Government Agencies.

Year	Price of power tiller	Horse power	Amounts of Subsidy	Amounts of loans	Interest rate (month)	Terms of loan (year)
1957	24,000	6–7	5,000	19,000		
1960	55,000	10	—	28,000	1.2	3
1961–1963	55,000	10	—	50,000	0.99	5
1964	55,000	10	—	50,000	0.90	5
1967–1968	57,500	13	—	56,000	0.75	5
1969	59,500	14	3,000	56,000	0.75	5
1970	53,000	14	3,000	50,000	0.75	5
1971*	50,000	14	5,000	45,000	0.60	6

* Special loans made by government agency to the farm machinery custom work teams organized by the Farmers' Association.

Source: Data obtained from Erhlun township office.

farm income was 2 percent less than on general farms, even though their farm receipts were 5.8 percent higher.

The productivity of family labor on farms of power tiller owners was 35.2 percent higher than that on general farms.

The more intensive cultivation of rice by machinery owners brought about 10.6 percent higher yield than that on general farms.

Table 12 compares the labor efficiency on farms of power tiller owners with that on general farms in the central rice region.

Changes of Capital Utilization and Its Efficiency

Farmers burden for owning power tiller

Loans for farm mechanization have been extended to farmers by a government agency, the Provincial Food Bureau, and by two agricultural banks, the Land Bank and the Cooperative Bank. Their loans are for 5 or 7 years, repayable in 10 or 14 equal semi-annual installments, at an interest rate of 0.75 and 0.99 percent per month or 9 and 11.88 percent per year.

The market price for power tillers and the rate of interest on loans to buy them have decreased to some extent in recent years (Table 13). However, the cost of a machine is still high relative to the income of an average farmer.

The annual fixed cost of a power tiller has been estimated at NT$20,300, including depreciation, interest and installment payments on loans. This is more than 3 times the average farm family surplus of the farm record keeping* farms in 1969. Comparisons are shown in Table 14.

Since it is difficult to enlarge the area of cultivated land except by increased cropping of the present limited land, farmers try to render machine service to others. According to a survey made by JCRR, about 55.7 percent of the total annual operating time of large power tillers (above 8 HP) was devoted to off-farm work (Table 15).

Changes of cost structure

According to the survey of machinery utilization in the central

* The farm record keeping project was put into effect in 1953. There were 500 farms in 36 townships taking part in this project in 1969 under the supervision of Provincial Department of Agriculture and Forestry.

Table 14. Farm and Family Income and Expense and Farm Family Surplus as Percent of Estimated Fixed Cost of Power Tiller (NT$20,300) 1969.

Item	Size of farm			
	0.5–1.0 ha.	1.5–2.0 ha.	Above 2.0 ha.	average
Farm income	115	218	305	168
Farm family income	184	289	376	236
Farm and non-farm exp.	118	228	327	178
Farm family surplus	14	40	73	27

Note: Based on tiller price of NT$50,000, interest at 0.75 percent per month, and machine life of 6 years.

Table 15. Utilization of Power Tiller (Large Type) in Taiwan.

	Work on own farm		Off-farm work		Other	Total
	Tillage	Transportation	Tillage	Transportation		
Hours/year	230.1	92.8	392.3	85.5	57.5	858.2
Percent	26.8	10.8	45.7	10.0	6.7	100.0

Source: A Survey of the Utilization of Power Tillers and Mist-blowers in Taiwan, March 2, 1970, Tien-song Peng.

rice region, the total expenses, farm and non-farm, of power tiller owners were 25 percent more than on general farms. The non-farm expenses of power tiller owners were NT$4,301, or 8.2 percent of the total expenses due to off-farm work with their machines. Expenditures for hired labor and for materials for farming were considerably higher on the farms of power tiller owners. Farm expenses per unit of cultivated land were as much as 30.8 percent higher on farms of power tiller owners than on general farms. Table 16 shows the differences in average production costs in the central rice region.

Changes of income level and capital efficiency

Farm machines are comparatively more expensive in the developing countries than in the developed countries. However, the increase in income provides an incentive for mechanization of farming.

Table 17 compares the average income of power tiller owners and general farmers in the central rice region of Taiwan. While farm expenditures of the power tiller owners were 14.6 percent more than for general farmers, their farm receipts were only 5.8 higher. But the power tiller owner's family income was 36.9 percent more than that of the general farmer. This difference is primarily attributed to the large non-farm income of the power tiller owners—346 percent more than that for general farms. The improvement of the family economy of machine-owner farmers in the rice region is very closely related to the amount of income from non-farm sources.

The family input-output ratio and rate of capital return on power tiller farms were, respectively, 5.7 percent and 7.6 percent higher than on the general farms. However, the farm input-output ratio on farms of power tiller owners was 7.5 percent less than on general farms. Therefore, the higher capital efficiency for farms of machine owners was due to higher earnings from off-farm work.

Joint Organization for Mechanized Farming in Taiwan

Joint farm operation has gradually developed from cooperation primarily in labor use to cooperation in capital utilization. In the meantime, the scope of cooperation has expanded from

Table 16. Comparison of Cost Structure between Power Tiller Owner Farms and General Farms in Central Rice Region, 1966.

	Allocation of Expenses of Farm Family				Average Input Per Ha. of Cultivated Land		
	Power Tiller Owner Farm		General Farm		Power Tiller Owner Farm	General Farm	Comparison
	Amount (NT$)	%	Amount (NT$)	%	(NT$) (A)	(NT$) (B)	$\frac{A}{B} \times 100$ %
Farm expenses	48,149	91.8	42,000	100.0	36,615	28,000	130.8
Fertilizer	13,506	25.7	12,912	30.8	10,271	8,608	119.3
Labor (hired)	5,398	10.3	2,048	4.9	4,105	1,365	300.7
Materials for farming	3,354	6.4	1,098	2.6	2,551	732	348.5
Depreciation & repairs	2,162	4.1	1,690	4.0	1,644	1,127	145.9
Interest	1,301	2.5	837	2.0	989	558	177.2
Feed expenses	8,324	15.9	7,912	18.8	6,330	5,275	120.0
Others	14,104	26.9	15,503	36.9	10,725	10,335	103.8
Non-farm expenses	4,301	8.2					
Total expenses	52,450	100.0	42,000	100.0			

Source: Survey report on the utilization of farm machinery, PDAF, December 1968.

Table 17. Comparison of Income Level and Capital Efficiency between Power Tiller Owner Farms and General Farms in Central Rice Region, 1966.

Value = NT$

	Power tiller owner farm (A)	General farm (B)	(A – B)	Comparison $\frac{(A-B)}{B} \times 100$
Farm assets	371,792	467,757	–95,965	–20.5 %
Liabilities	12,035	4,920	+7,115	+144.6
Farm capital	359,757	462,837	–103,080	–22.3
Farm receipts	94,733	89,540	+5,193	+5.8
Farm expenditure	48,149	42,000	+6,149	+14.6
Farm income	46,584	47,540	–956	–2.0
Non-farm receipts	30,980	5,978	+25,002	+418.2
Non-farm expenditure	4,301	—	+4,301	—
Non-farm income	26,679	5,978	+20,701	+346.3
Farm family income	73,263	53,518	+19,745	+36.9
Input-output ratio on farm	1.97	2.13	–0.16	–7.5
Input-output ratio on non-farm	7.20	—	—	
Input-output ratio on family farm	2.40	2.27	+0.13	+5.7
Rate of capital return (farm family income/farm capital)	0.2036	0.1156	+0.88	+7.6

single-crop production to the entire farm business. Numbers of participating families have also become larger, ranging from a few families to entire villages.

As has happened in such developed countries as Japan, the total number of part-time farmers has increased in Taiwan. Therefore, government agencies have encouraged farmers to organize joint operations that will facilitate efficient use of modern techniques and machinery. The scope and types of joint farming which are being demonstrated or experimented with under supervision of government agencies are as follows:

Joint operation of rice production

Local farmers' associations have been encouraged to establish joint operation of rice production since 1963. Joint operation is undertaken by 10 or more farmers on about 10 or 15 hectares of paddy.

By 1969 a total of 842 places (blocks), which included 26,554 farmers and 15,027 hectares of paddy, had been organized voluntarily. According to information from the Provincial Department of Agriculture and Forestry, yields were increased 13.92 percent and profits averaged 30.41 percent higher on the joint operation farms as compared with average farms in the same areas.

Benefits attributed to joint operation of rice production include unification of varieties and farming practices, promotion of efficient and scientific use of production factors, application of farm mechanization with increase in labor efficiency through group work, development of a spirit of cooperation among members of the group, indirect influence upon neighbors for better farming, and promotion of social changes in the community that facilitate economic development.

Experimentation in cooperative farming

Due to the success of joint operations in rice production, the agricultural organization authority (PDAF) further initiated a cooperative farm management program in 1966 to cover the entire business of the members and to increase their farm management efficiency and improve their livelihood.

In this program, groups of 3 to 7 neighbor farm families having, together, about 5 hectares of land were encouraged to form cooperative farms. The major items of cooperation were joint procurement and utilization of new machinery and construction of farm facilities such as underground water for irrigation and domestic use, items usually too expensive for a single farm. These new investments have been accompanied by structural changes on the farms.

As of 1970 this program was still in the demonstration stage. Thirty cooperative units including 374 farm families with 465 hectares of land were operating and demonstrating under the supervision of the Agricultural Improvement Stations. Table 18 shows a comparison of farm income as reported by PDAF.

In general, technological advancement through joint operation of single-crop production and extension to cover the whole farm business through cooperative management has greatly lifted both land and labor productivity. Modern power machines as well as farm labor are used economically for maximizing farm family income. This result, of course, is obtained by intensified utilization and better combination of production resources.

Joint operation or cooperative farm management is considered

Table 18. Comparison of Farm Income between Cooperative Farms and Check Farms in 1970.

	Project farms (A)	Check farms (B)	Comparison $(\frac{A}{B}) \times 100$
	(NT$)	(NT$)	
Average farm income per ha.	29,244	19,773	148
Average farm income per family worker	104	68	153
Average farm family income	74,388	40,494	184

Note: The average sizes of project farms and check farms were 1.24 and 1.49 hectares, respectively.

not only a way to increase efficiency at the farm level but also a positive measure to step up the national economy of Taiwan. However, extension of joint activities requires long-term, low-interest loans from outside for investment in modern equipment and facilities on farms. The availability of such capital is essential to expand the joint activities for farm mechanization and agricultural modernization.

Experimentation in modernized agriculture in selected areas

To accelerate agricultural growth, a Working Group for the Promotion of Modernized Agriculture was set up in the Joint Commission on Rural Reconstruction (JCRR) in May 1970. It includes technical experts in economics, farmers' organization, crops, animals, and finance.

This group is responsible for conducting and studying co-operative mechanized farming for future agricultural development. Two pilot project areas, each with approximately 100 hectares of cultivated land, have been selected to start this year as experimental zones in the central rice region and the southern rotational farming region.

The experiments will include new cultural methods and farming systems using mechanical operation, the combination of different types of machines in the operation, the profitability of mechanical operation, possibilities through adoption of these things in joint or cooperative farming, practices in supplying farm inputs, marketing, and processing of farm products by farmers' organizations, etc. They will be conducted in cooperation with related agencies including the Provincial Department of Agriculture and Forestry and the Provincial Farmers' Association. The personnel of township farmers' associations, township offices, and District Agricultural Improvement Stations will be working closely with the farmers in the project area.

This experiment covers social, technical, and economic aspects and provides positive direction for farm mechanization and modernization. It may lead to efficient farm management throughout rural Taiwan.

Results of the project will be checked and examined jointly by concerned members of the Working Group in late August, when the first rice crop is harvested.

Conclusion and Recommendations

As a result of continued economic development of Taiwan, the agricultural labor force and capital are flowing out to the non-agricultural sector. The resulting increase in wage rates, decline of land prices, decrease of the cropping index, etc., together with the small size of farms and low purchasing power of farmers, have greatly hindered farm modernization as well as farm mechanization.

To attack these problems and to raise farm income by better farm management, the new agricultural policy of Taiwan has set out farm mechanization as of first priority in further agricultural development measures.

The power tiller is still the backbone of modern farm machinery, totalling 24,640 units in 1969. For every 36 farm households or every 37 hectares of cultivated land there is a power tiller in Taiwan. The average annual increase in power tillers was 2,500 in 1966–67 and 3,700 in 1968–69. Each additional power tiller replaced 4 to 6 head of draft cattle.

The price of a 14 HP power tiller was NT$53,000, equivalent to US$1,325 in 1970. For small size farms this machine, of course, is costly. However, the benefits from introducing a power tiller or any type of modern machinery on a farm can be measured in terms of labor saving and production increase.

In the central rice region of Taiwan, farms of machine owners achieved about 10.6 percent higher yield of rice, 35.2 percent higher productivity of family labor, 36.9 percent higher family income, a 5.7 percent higher farm input-output ratio, and a 7.6 percent higher rate of capital return as compared with the corresponding figures for the general farms. Both labor and capital efficiency were improved.

The potential savings of labor cost on machine-owner farms are limited due to continued intensive use of their resources. The intensive farming system was maintained, and the cropping index was higher than that on the general farms.

The real wage rate has increased much faster than the rate of charges for custom work by power tillers. The widening difference of these indices will accelerate the adoption of machines on farms. However, there is competition among machines for custom work as the number of machines increases, and the profitability of custom work may tend to be less.

At the present time, the demand for other machines, such as power transplanters and harvesting machines, is increasing, but they are still few in total number. This may be attributed not only to financial ability, small size of farm, and less experience in using the new machines, but also to the shortage of new cultural methods to go along with them. Indeed, further intensification of farm management of Taiwan will depend to a large extent upon advance in technology and science, on the one hand, and upon study of practical problems arising in the field, on the other.

As farm mechanization is intensified, several new types of machines with bigger capacity will be extended to all the farms through custom work or cooperative use. In Taiwan, there are experimentation and demonstration programs of joint and cooperative farm management under supervision of agricultural agencies. However, social and economic research should be strengthened along with technical experimentation.

From the economic point of view, efficiency of farming will improve through joint or cooperative methods. However, the promotion and extension of joint or cooperative farms will not only require outside capital for investment but will also depend on such means as guarantee of land ownership, methods of sharing income and expenditures, organization, etc. Therefore, research institutes and government need to study and enact positive measures relating to fragmentation of cultivated land, expansion of private farm size, improving farm organization, and encouragement of joint or cooperative farming through financial and technical support.

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NEED FOR FARM ADJUSTMENT TO A GROWING ECONOMY AND CONDITIONS FOR FARM MECHANIZATION

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Farm work simplification is urgently required in Korea to make up for the labor deficit within the farm sector and to enable the farm sector to release more labor to the nonfarm sector and at the same time expand production and introduce new farm products to fulfill the rapidly growing demand resulting from the nation's economic growth. Farm work simplification can also play a very important role in the nation's economic development through increasing productivity and factor earnings in the farm sector itself.

This requirement could be met in large part by farm mechanization. However, the high cost of capital inputs relative to labor cost and the small size of farms—conditions prevalent in the less developed countries—are considered obstacles to farm mechanization. Then, is farm mechanization hopeless in Korea?

A main thesis of this paper is that a substantial labor withdrawal out of the farm sector is a necessary condition for farm mechanization, and that small farm size will not be an important restraint to it, once supplies of new and better inputs are available. The paper will also emphasize that farm mechanization should be viewed as a means of rural development and of farm adjustment to the nation's economic development and as a contribution to economic growth. It facilitates specialization and thus helps eliminate the income gap within the farm sector and between sectors.

Economic Growth and Farm Adjustment

The obvious facts are, first of all, that the Korean economy recently has been growing rapidly. Since 1965, the annual growth rate of the gross national product (at constant prices) has been more than 10 percent, population growth about 2 percent. And secondly, the source of the nation's economic growth has been the expansion in the general industrial sector.

Hence the process of economic development thus far has appeared to have its mainspring in the industrial-urban complex. Productivity and aggregate production in the farm sector have remained relatively unchanged.

These facts give rise to several problems to which the farm sector has to adjust to make a sound contribution to the further continued and rapid growth of the nation's economy. The impacts of the sustained rapid growth of the economy on the farm sector can be summarized as follows.

Labor force withdrawal

One of the important features of economic development is a continuing transfer of rural labor to the nonfarm sector. This decreases the proportion of population or of working people in the farm sector and releases labor to engage in producing more goods and services that are consistent with consumers' preferences revealed in the market.

This is a significant role of agriculture in economic development. Thus, if the farm sector is to continue to contribute to economic development, it must continuously release labor. But to make this contribution possible, agricultural productivity must be increased. That is to say, the farm sector must have a labor surplus, and to have this surplus above the long-established equilibrium in the past, technology which can be substituted for labor must be developed and adopted. However, farm labor force withdrawal seems so far to be taking place in Korea with little introduction of effective innovations.

Let us now look at some empirical data concerning labor withdrawal and its impact on the farm sector. As shown in Table 1, rural population decreased by 1.4 percent during the period 1965–69. However, there are differences among provinces in the rates of population transfer.

In spite of an increase in Korean rural population of 1.7 percent from 1965 to 1967, in Kyungki and Kyungnam provinces the rural population had already started to decline in this period.

Table 1. Percentage Change in Farm Population, Selected Provinces, 1965–69.

Province	Increase (+) or decrease (−)	
	1967/1965	1969/1965
Korea as whole	+1.685	−1.408
Kyungki	−0.215	−4.411
Kangwon	+3.579	−1.532
Chungpook	+3.216	−0.864
Chungnam	+1.059	−1.514
Chonpook	+4.242	+0.605
Chonnam	+3.316	+3.270
Kyungpook	+0.901	−3.307
Kyungnam	−0.417	−3.168
Eastern Kyungnam	−1.946	−3.867
Middle Kyungnam	−0.453	−3.389
Western Kyungnam	+0.482	−2.594

Source: Ministry of Agriculture and Forestry.

This seems to be the effect of so-called locational matrices: the two provinces surround, respectively, the Seoul and Pusan-Ulsan economic development centres.

Since then, the more recently created economic development centre in the Taegu-Pohang area has caused the rural population in Kyungpook province to decrease rapidly.

Peripheral areas where there are no such centres have continued to increase in rural population—for example, Chonnam and Chonpook provinces. This seems to stem from lack of information or from the fact that "uncertainty about nonfarm opportunity may increase with distance".[1]

Also the rate of transfer is different depending on location even within a province. In the eastern part of Kyungnam Province, where the Pusan-Ulsan centre is located, the population withdrawal rate is much greater than in the western part. The implication of this discussion is that creation of more economic development centres will certainly induce farm population to decline further.

At any rate, it is very certain that the rural population as a whole has now definitely started to decline absolutely. The impact on agricultural production will differ depending on the age group of the migrants. Jin H. Park has shown in an earlier paper in this volume that a disproportionate share of the migrants are younger workers, so that the rate of decrease in the working force is much greater than in the rural population as a whole. Indeed, this has caused the remaining farm people to feel a shortage of labor, especially in labor-peak times.

This actually has been reflected in farm wage rates, as shown in Table 2. Prices of farm products and of capital inputs rose about 60 to 70 percent from 1965 to 1969, whereas farm wage rates rose nearly 120 percent. This figure is the national average. We can easily imagine that there are large differences in wage rates among areas, depending on the degree of labor withdrawal.

As new and better inputs are being introduced to the farm sector, the marginal returns to the conventional inputs, labor and land, are likely to increase. The prices of such inputs would tend to increase accordingly. Then can it be interpreted that the comparatively high wage rates are associated with a comparable increase in labor productivity in the farm sector? We do not have

Table 2. Indices of Farm Prices and Wage Rates in Korean Farming and Manufacturing, 1965–69 (1965 = 100).

Year	Index of prices received by farmers	Index of prices paid by farmers	Index of farm wage rates	Index of wage rates in manufacturing
1965	100.0	100.0	100.0	100.0
1966	106.1	112.2	116.9	117.8
1967	121.5	127.0	142.7	144.3
1968	142.3	152.2	178.3	182.6
1969	162.4	167.7	216.4	245.0

Source: National Agricultural Cooperative Federation.

appropriate data to test this. Table 3 shows some evidence: average labor productivity (gross product per worker) in the farm sector increased about 21 percent from 1965 to 1969, whereas that in the nonfarm sector increased 50 percent.

Table 3. Labor Productivities in Farm and Nonfarm Sectors (Gross Product per Worker Employed), 1965–69.

Year	Labor Productivities (won per worker)			
	Average	Farm sector (A)	Nonfarm sector (B)	A/B
				percent
1965	94,561	62,293	135,859	45.9
1966	105,534	68,574	152,069	45.1
1967	111,640	65,733	162,980	40.3
1968	121,728	66,931	176,821	37.9
1969	139,744	75,167	203,949	36.9

Source: The Bank of Korea and Economic Planning Board.

The ratio for the two sectors has been changing more and more in favor of the nonfarm sector. The wage rates in both sectors have tended to rise faster than productivity. However, the high wage rate in the farm sector seems to be affected more by that in the nonfarm sector (opportunity cost) than by productivity.

Farm income

We are faced with two problems simultaneously which are seemingly incompatible; a food problem and a farm problem. The low labor productivity in the farm sector results in low output per capita compared to the nonfarm sectors. Thus the earning power of farmers, or the farm income per family, is quite small compared to that of the wage earners' family in the city, and the difference is becoming greater over time, as shown in Table 4.

The farm problem as well as the food problem (inadequacy

Table 4. Per Capita Disposable Incomes of Farm and Wage-Earner Families, 1965–1969.

Year	Disposable Income			Ratio	
	Farm families (A)	Wage-earner families			
		All cities (B)	Seoul (C)	(A/B)	(A/C)
	········ won per capita ········			percent	
1965	17,094	20,954	23,954	81.6	71.4
1966	20,043	27,404	35,234	73.1	56.9
1967	23,635	39,680	49,505	59.6	47.7
1968	28,831	46,134	56,338	62.5	51.2
1969	35,134	57,871	68,249	60.7	51.5

Source: Ministry of Agriculture and Forestry and Economic Planning Board.

of food supply) mainly stem from low agricultural productivity, due to the slow rate of technical change. However both problems are basically related to product supply elasticity, which, in turn, is conditioned by the demand for and supply of new and better inputs.

Differential growth rates of demands for individual farm products

We have seen already that the per capita income of farm families has been growing by more than 10 percent annually, while the population growth rate has dropped to approximately 2 percent annually. On the other hand, the capacity to produce food to feed the nation's people does not seem to have grown as fast as the demand has. The obvious consequence is an increasing deficit of food supply, so that the nation has had to import more and more rice—0.125 million tons in 1967, 0.240 in 1968, 0.800 in 1969, 0.600 in 1970 and 1.105 in 1971.

The insufficiency of grain production relative to the nation's needs has occurred in spite of extremely low income elasticities of demand for individual food grains (traditional products) (Table 5), whereas income elasticities for such foods as meat, eggs, milk, fruits, and vegetables (new products) are much larger. This is likely to disturb the equilibrium of factor earnings among enterprises. Hence farmers need to adjust to differences in growth rates of demand for individual farm products. In fact, farm earnings per unit of land when winter vegetables are introduced into the crop sequence with rice, for example, are much greater than when the traditional enterprise sequence, rice and barley, is followed in the same village.[3]

The price elasticities of demand for the traditional food grains also are generally low compared to those for new products. Furthermore, there is a significant upward trend in livestock prices whereas such a trend cannot be found in food grain prices.[4] This suggests that the new products can be expanded profitably considerably beyond the annual growth rates of their demands conventionally calculated.

In summary, we have seen that the rural working force has started to decline, and that the farm wage rate is increasing more rapidly than labor productivity. Will this alone induce farm

Table 5. Income and Price Elasticities of Demand for Selected Farm Products[2].

Product	Elasticity		Type of data used
	Income	Price	
Rice	0.004	−0.205	Time series
Barley	−0.078	−0.662	Time series
Wheat	0.153	−0.781	Time series
Soybeans	0.342	−0.641	Time series
White potatoes	−0.001	−0.764	Time series
Sweet potatoes	−0.412	−1.308	Time series
Beef	2.420	−1.000	Time series
Pork	1.382	−0.973	Time series
Eggs	1.621	−0.850	Time series
Milk	3.000	–	Cross section
Fruits and vegetables	0.928 – 1.903	–	Cross section

mechanization? Is this a necessary, as well as a sufficient, condition for farm mechanization? Or is this only one reason for farm mechanization?

Farm mechanization is required, first of all, to offset the labor deficit that has appeared recently. The deficit should be considered as due not to be the transfer of too many workers out of the farm sector, but as due to the failure to provide technology or capital inputs that could substitute for them. Secondly, farm mechanization is also required to enable the farm sector to release more labor in order to accelerate the nation's further economic development. This is so because, without some substitutes for labor input, further withdrawal of labor will, ceteris paribus, cause the food supply to drop, which means that the food demand-supply gap will increase, and, in turn, the nation's over-all economic development will be delayed. Thirdly, the labor required for production of traditional products should be reduced so that new products can be introduced or the intensity of both types of products can be increased, thereby offering some solution to the income problem that farmers simultaneously face.

Conditions for Farm Mechanization

We have shown the need for advanced technology to make farm work simplification possible so that the labor requirement per unit of production can be reduced, especially in industrialized areas. We also know that this can be done largely by farm mechanization. We now ask: What conditions should we specify for farm mechanization, or what conditions are necessary for it to generate the greatest possible productivity and welfare effects?

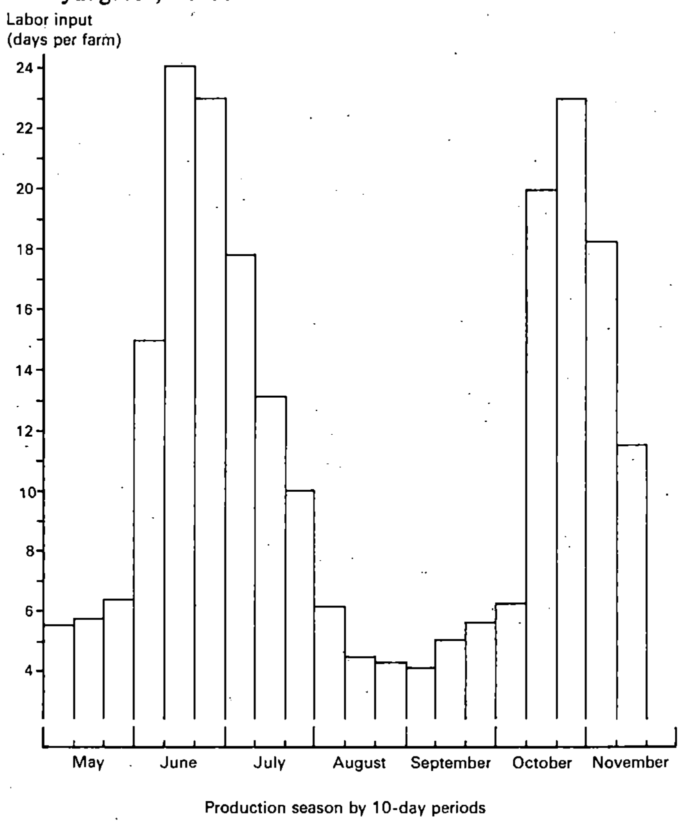
1. First of all, a set of new forms of technology must be available with relatively elastic supply conditions.
2. Productivity or input-output relationships of the new forms of inputs also must be known with some degree of certainty.
3. The price of the new and better input, farm machinery, should decline relative to its conventional counterpart, labor, and in addition its productivity should increase relatively.
4. The capital limitation, internal or external, which the farmer faces should be relaxed through capital accumulation by the farmers themselves or by an increased supply of credit at a low interest rate.

5. In addition to fulfillment of the required physical conditions for farm mechanization, farmers should be equipped with the needed skill and technical knowledge concerning machinery operations.

What Types Of Operations Should Be Simplified?

To determine priorities in work simplification we need to analyze the labor requirements by type of work, by enterprise, and over the production season. Figure 1 shows total labor inputs for crop production per farm, 1969, estimated from the average of 38 farms in Jeungto-ri, Jeukjoong-myun, Hapchon-gun,

Fig. 1. Total Labor Input for Crops per Farm by Selected Production Seasons (10-day periods for each month), Estimated from 38 Farms, Jeungto-ri, Hapchon-gun, Kyungnam, 1969.



Kyungnam. The sample averages of arable land, cultivated land, and land planted to rice and barley were, respectively, 1.31, 2.25, 1.03 and 0.81 hectares. Although the farm size is somewhat larger than the national average, the figure implies that a labor force of at least 2.3 or 2.4 man-equivalents per farm is required, on the average, to maintain the present production level unless labor substitutes become available or the enterprise combination changes. This is true because the labor requirement at labor peak times, middle and late June and middle and late October, amounts to more than 20 man-days per 10-day period.

Actually, it is at these peak times that we feel the labor shortage. Because agricultural production is a biological process, labor available even in early June cannot help to solve the labor deficit in middle or late June. Farmers determine the number of laborers required on the farm on the basis of the maximum requirement of labor at these peak times for a given land area, since the total labor supply at these times within a village is extremely inelastic.

The available labor force per farm in this sample was about 2.5 man-equivalents, and we did not count labor required for livestock production. Hence further withdrawal of labor would force one of two alternatives: substitution of capital inputs for

Table 6. Total Farm Labor Requirement and Labor Required for Rice and Barley Production at Peak Times, Days per Farm, Jeungto-ri, Hapchon-gun, Kyungnam, 1969.

	June		Early July	October		Early Nov
	middle	late		middle	late	
Total labor requirement	24.1	23.1	17.8	20.0	23.2	18.2
Labor for	6.3	17.8	14.0	14.5	6.7	6.6
rice	(26.2)	(77.3)	(78.4)	(72.5)	(28.8)	(36.2)
Labor for	13.8	2.2	–	2.7	16.4	10.8
barley	(57.5)	(9.5)	–	(13.7)	(70.9)	(59.2)

Figures in parentheses are percentages of period totals.

Table 7. Proportion of Labor Requirement by Types of Operations for Rice and Barley at Summer Labor Peak Time, Sample Average of Kyungnam Province, 1965.

Rice production	100.0	Barley production	100.0
Transplanting	41.3	Threshing	39.5
Weeding	19.1	Harvesting	34.8
Land preparation	11.8	Drying	10.4
Irrigation	8.2	Carrying	8.2
Other	19.6	Binding	7.1

Source: Research Institute of Agricultural Economics, Ministry of Agriculture and Forestry.

labor, or contraction of agricultural production.

Table 6 shows average labor input on the sample farms for the main enterprises, rice and barley, at the peak times. The sample can be said to be typical of farms in southern Korea in terms of production combination, crop sequence (two-crop system), and resource holdings. It should be noted that rice and barley were being threshed by machine.

We can easily see that in both peak times most of the farm labor required is for rice and barley. Thus the first priority is to invent methods for work simplification connected with these products as long as they remain the main products.

Not only is the labor required for the two products more than 80 percent of the total requirement at both peak times, but we also need to reduce the unit cost of producing them so that their supply functions shift to the right, and we need surplus labor either for producing nonfarm products or for introducing new products whose income elasticities are relatively high, as indicated above.

We ask next, what specific operations can or should be simplified? Tables 7 and 8 indicate the proportion of the labor requirement for each type of operation for both products at both peak times. These data imply that most operations are concerned with rice transplanting and barley harvesting at the summer labor peak, and with rice harvesting and barley seeding

Table 8. Proportion of Labor Requirement by Types of Operations for Rice and Barley at Fall Labor Peak Time, Sample Average of Kyungnam Province, 1965.

Rice production	100.0	Barley production	100.0
Threshing	41.6	Seeding	53.2
Harvesting	23.6	Carrying fertilizer	20.6
Drying	14.2	Fertilization	15.7
Carrying	10.8	Land preparation	10.5
Binding	9.8		

Source: Same as Table 7.

at the fall peak. Therefore we may conclude that these operations should be simplified to ensure a sufficient saving of labor.

Can The Conditions For Farm Mechanization Be Fulfilled ?

Now that we have seen what kinds of operations we need to simplify, we shall examine whether the economic conditions for farm mechanization are readily fulfilled.

1. *Availability and productivity*.

Threshers, pumps, sprayers, and chemicals for weeding have been introduced to a considerable extent already. They seem to have contributed substantially to work simplification, particularly in terms of making work easier. However, except for the thresher, they have little or no effect on labor time required in the two peak periods.

Motor tillers are now available, but the supply is very limited. They can be used for several purposes as a power source for threshing, pumping, carrying, land preparation, etc. Thus if certain demand and supply conditions are improved, as will be discussed in the next section, the demand for motor tillers will be likely to increase substantially.

Nevertheless, simplification of the work connected with such important operations as transplanting and harvesting will remain unsolved, and the over-all labor reduction will not be great, since the operations that can be done by motor tillers are limited, and moreover their efficiency is not very great. The most important farm machines—the rice transplanter and the grain harvester (which may be a combine, binder, reaper, or mower)—are not available yet. Accordingly their productivities are not known with any degree of certainty. The availability and productivity of these machines seems to be the most important condition for new and better technology to be adopted, as will be discussed in a later section.

2. *Price and capital limitation.*

Prices of capital inputs seem to be high in Korea. For example, prices in terms of rice for a motor tiller and a sprayer are, respectively, 2.96 and 2.37 times as much here as in Japan.[5] One might say that the input-output price relationship should not influence the factor combination; what is important is the ratio between prices of the new and the conventional inputs (machinery and labor). However, particularly if there is a serious capital limitation problem, the indivisible nature of an input such as a farm machine may prevent substitution of it for labor, even if the price ratio were in favor of the substitution. In fact, in addition to the price of machinery being high, the farm income surplus is relatively low. Consequently, for example, it takes about 9 years for a farmer to pay for a motor tiller out of the average farm surplus realized in Korea, whereas it took about one year in Japan in 1968.[6]

3. *Technical knowledge and other factors.*[7]

Power-driven rice and barley threshers and sprayers are widely used in Korea. Most farmers are familiar with operating the prime motor, because it has long since been used in our rural society for milling and water pumping. Moreover, the cylinders of the threshers are very similar to those used for a long time.

However, the case of the motor tiller seems to be somewhat different. In order to use it fully and perfectly, more skill and technical knowledge are required. In addition, certain physical conditions must be met.

Table 9 shows the distribution of farms in the Chinju area having motor tillers by the ratio of field work to nonfield work done by the motor tiller. Note that about 30 percent of the farms did not use the motor tiller for field work at all, and on about 70 percent of the farms, field work was less than 20 percent of the total utilization. It appears to be used relatively more for field work on large farms, by farmers in the age-group of 30–40,

Table 9. Distribution of Farms by Relative Use of Motor Tillers for Field Work and for Nonfield Work, 99 Farms Owning Motor Tillers, Chinju Area, 1970.

	Ratio of field work to nonfield work (percent)					Total or average
	0	1–10	11–20	21–30	over 30	
No. of farms	29	20	19	9	22	99
Average farm size (tanbo)	19.9	22.5	12.6	15.1	20.3	18.8

Note: Transportation within the farm is not counted as field work.

and by middle school graduates.

The same farmers were asked how much of various operations on their own farms was done with the motor tiller. The results are shown in Table 10.

Transporting products and fertilizer was the type of work most favored on the farm. It is simple and requires little skill and technical knowledge. In second place was land preparation. Least use was made of tillers for seeding and cultivation—yet these are perhaps the operation most in need of work simplification.

Table 10. Percentage of Specified Operations Performed by Motor Tiller, 99 Farms Owning Motor Tillers, Chinju Area, 1970.

	percent
Plowing land for rice	42.7
Leveling land for rice	36.0
Preparing land for barley	39.2
Barley seeding	18.3
Barley cultivation	15.4
Preparing upland for summer crops	17.8
Summer crop cultivation	6.4
Transportation within the farm	49.5

The reasons given by the farmers for not using motor tillers more extensively for field work are ranked in Table 11. Physical conditions such as drainage, land rearrangement, and farm roads appear to be important restraints upon the field use of machines. Skill and technical knowledge, however, are more important than appears in the table. In view of the productivity of the motor tiller, the answer "not efficient" may have two bases: one the physical field conditions and the other lack of skill and knowledge. Thus we can say that investment in human capital development, in research to provide the necessary technical knowledge concerning adaptation of farm practices to farm mechanization and in the dissemination of such knowledge, are of vital importance also.

Table 11. Relative Importance (Weighted Ranking Average) of Reasons given by Farmers Why Motor Tillers Could Not Be Used for Specified Operations, 99 Farmers owning Motor Tillers, Chinju Area, 1970.

	percent
Land preparation for rice	
No land rearrangement	25.6
Wet paddy	21.8
No road	20.1
Not efficient	18.1
Lack of skill	14.5
Barley seeding	
Wet paddy	27.5
No road	26.0
Not efficient	24.8
Lack of skill	21.7
Upland summer crop seeding and cultivation	
Inter-crop	27.3
Not efficient	27.3
No road	25.9
Lack of skill	19.5

In summary, to facilitate farm mechanization: (1) the needed machinery must be developed, (2) the supply conditions of the machinery industry must be improved so that an adequate quantity can be supplied at a reasonable price, (3) capital accumulation or credit supply at a moderate price must be increased, (4) technical knowledge must be developed and disseminated, (5) physical conditions, which are mostly infrastructural to individual farms, such as irrigation, drainage, land rearrangement building, farm roads, and the like, must be improved, and finally (6) a repair service system for the machinery must be established.

Not all of these requirements can be met simultaneously in the near future for every place and every farm. Even if they could, farm mechanization would not be profitable or economical simply because per unit cost still would be high due to the small size of farms, as most agricultural economists insist.[8] Even given new forms of capital goods and technical knowledge, it would be still true that "the supply of capital is small and capital is relatively expensive. Under these conditions, even if all farmers had complete knowledge about the productivity of capital innovations, agriculture optimally would still be based principally on labor".[9]

Then, is farm mechanization hopeless in Korea? These opinions are rather naive in the sense that they do not count the concept of farmers' marginal valuation of family labor and the possibility of custom or group use of farm machinery.

Process of Farm Mechanization in Korea

What a farmer needs for the simplification of farm work is not a stock of machinery, but machinery service. The high price of machinery, small farm income surplus, and small farm size apparently do not allow most individual farmers to own their own stock of machinery. This has been true in the past and will be true for some time in the future. Nevertheless, Korean farmers have found ways to get farm machinery service as a basis for farm mechanization.

Introduction of mechanical threshers

The hand cylinder rice thresher and the water pump were the first farm implements or machines supplied from the non-farm sector to be introduced into rural Korea. It was around 1930 when these were introduced in western Kyungnam.

At that time, not every farm was able, nor did it need, to own them. Machinery service was supplied by innovators who realized its productivity and grasped the advantage of custom work. Especially in the case of the rice thresher, the innovators were not necessarily large farmers, maybe because the rich farmer had no economic incentive to make money through custom work. Because of capital limitation and risk aversion, the machine was usually acquired under joint ownership of a couple of farmers, brothers or neighbors. First they demonstrated its productivity and value for work simplification, and this induced a demand for the service.

In the second stage, with improvement in the economic situation of farmers and for sake of better timing of the operation, most farms above middle size acquired their own hand cylinders, apparently after land reform (1950).

Next, power-driven threshers for barley and for rice appeared. They started to become popular among farmers in western Kyungnam around 1955 and 1960, respectively. The pattern of motivation and ownership for these machines was exactly the same as in the case of the hand cylinder. The service of the barley thresher was rapidly adopted and became very popular among farmers since its productivity is great relative to the service price.

The case is somewhat different in using the service of the rice thresher. The efficiency, in terms of labor requirement, of the hand-cylinder and of the power-driven thresher of the type commonly used in western Kyungnam is almost the same. Nevertheless, almost all farmers, regardless of farm size, hire this service.

Is this malallocation of resources? Keep in mind that much arduous labor is avoided by hiring the service. This phenomenon may be explained on the basis that as the farm income level increases, compared not with nonfarm income but with the past income level, the marginal utility of income decreases whereas the marginal disutility of family labor rises. In Nakajima's terms[10], the curve of "marginal valuation of family labor" shifts upwards as (asset) income increases, causing the machinery service to be substituted for family labor input. (This is somewhat similar to what is called "income effects" in the theory of demand.)

This implies actually a so-called backward-sloping labor supply curve in the short run. However, if a new income stream source can be found which shifts the curve of marginal productivity of labor to the right, we would expect that the total input level of family labor will certainly be increased.

Patterns of machinery ownership

Now let us look at the type of machinery ownership and how farmers are supplied with machinery service. To support the above discussion and to provide some basis for farm mechanization policy, 195 farmers in the Chinju area who own a rice or a barley thresher or a motor tiller were surveyed. Of the farmers surveyed, 85 percent were reported to own two or three of the machines, 44 percent owned both rice and barley threshers, and 37 percent owned all three machines.

This implies that the farm machinery holdings are more or less concentrated on a few farms. One good reason for this is that the same prime motor can be used for both threshers, and the motor tiller can provide power for threshers as well. In a sense, they are complementary; the marginal cost of an additional machine may be relatively little. For another thing, skill and technical knowledge are required for the operation of the machines, so that their possession tends to be confined to farmers who are more or less specialized in machinery operation.

Perhaps this is a reason, in addition to improvement of the farm economy and decrease in uncertainty, why joint ownership has almost disappeared, as Table 12 shows. Note also that cooperative ownership was found only in the case of the motor tiller. (Some high-speed sprayers and water pumps are known to be owned and operated by local governments.)

Then we ask: Are the owners of the machines the large-size farmers who can utilize them economically (income effect)? Do they have an income surplus large enough to demonstrate psychological or asset effects (demonstration effect)? Or what is the main motivation to possess the machines?

The most important motivation is custom work as an off-

Table 12. Types of Ownership of Farm Machines, 195 Farms, Chinju Area, 1970.

Type of ownership	Rice threshers	Barley threshers	Motor tillers
Individual	159	161	95
Joint	6	7	3
Cooperative	0	0	1
Total	165	168	99

farm job opportunity. According to Table 13, the great majority of farms owning rice or barley threshers or motor tillers do some custom work.

Furthermore, the average size of farms that do custom work is 16.5 to 17.0 tanbo, whereas that of farms that do no custom work is around 21 to 24 tanbo. Thus we hypothesize that a large farm has farm machinery for home-farm work, whereas a comparatively small size farm uses its machinery for custom work as well as work on the home farm. (Variations from this tendency will exist, of course, depending upon family size, educational level, economic status of the family, and the like.)

Once again, looking at Table 13, as the ratio of custom work increases the farm size declines, but less than proportionally. Inversely speaking, as the farm size decreases the custom work ratio increases more than proportionally. Note particularly that 32 and 40 percent, respectively, of rice and barley thresher owners make more than four times as much use of them for custom work as for work on the home farm, and their average farm sizes are only 11.2 and 14.2 tanbo, respectively.

However, the case of the motor tiller is somewhat different—it is used relatively less for custom work. There seem to be some good reasons for this. First, motor tillers are not used very much for field work, for the reasons previously cited. In addition, many of the farmers who had motor tillers were engaged in animal husbandry (dairy and poultry), running a mill or a brewery, or the like. On these farms the motor tiller was used

Table 13. Distribution of Farms by Ratio of Custom Work to Home Farm Work, 195 Farms, Chinju Area, 1970.

Machine	No custom work	Ratio of custom work to home farm work					Total or average
		less than 1	1–2	2–3	3–4	over 4	
Rice thresher							
No. of farms	20	19	26	26	21	53	165
Average size of farms (tanbo)	23.6	22.4	18.5	21.4	16.2	11.2	17.4
Barley thresher							
No. of farms	17	19	22	22	14	67	161
Average size of farms (tanbo)	21.2	25.6	18.7	18.0	17.9	14.2	17.0
Motor tiller							
No. of farms	24	48	9	18	—	—	99
Average size of farms (tanbo)	24.2	17.8	16.7	15.2	—	—	18.8

Table 14. Distribution by Size, Farms Owning All Three Machines (Rice Thresher, Barley Thresher, and Motor Tiller) and Ratio of Custom Work to Home Farm Work for Each Machine, 72 Farms, Chinju Area, 1970.

Farm size (tanbo)	No. of farms	Ratio of custom work to home farm work		
		Rice thresher	Barley thresher	Motor tiller
10 or less	20	7.9	9.5	8.5
11–20	23	3.6	3.1	1.1
Over 20	29	1.6	1.8	1.3
Total or average	72	4.0	4.4	3.2

more as a means of transportation.

As noted above, 37 percent, or 72, of the 195 farms surveyed had all three machines and may be viewed to be specializing in supplying machine service. Table 14 shows the distribution of these farms by farm size and ratio of custom work. The data also support the hypothesis set up above. More important, these specialized farms are not predominantly large farms—they are almost equally distributed among all classes of farm size. Originally, motor tillers were officially alloted to farms of more than 20 tanbo in Kyungnam Province. Nevertheless, 60 percent of the tillers now belong to farmers operating less than 20 tanbo, who may be said to have a strong incentive for custom work. (See also Table 15.)

What kinds of factors affect the rate of custom work? Identification of the factors is important since the average ratios of custom work to home farm work for rice and barley threshers and motor tillers are 5.0, 5.7 and 1.2, respectively, as shown in Tables 15–18, which indicate that farm work simplification will be achieved more through custom work than through home farm work. This will be more efficient in the sense that the

Table 15. Ratio of Custom Work to Home Farm Work by Farm Size, 195 Farms, Chinju Area, 1970.

	Farm size (tanbo)				Total or average
	10 or less	11–20	21–30	over 30	
Rice thresher					
Custom work ratio	8.8	3.5	2.6	2.4	5.0
No. of farms	56	51	40	18	165
Barley thresher					
Custom work ratio	9.7	3.7	3.6	2.2	5.7
No. of farms	61	49	41	17	168
Motor tiller					
Custom work ratio	1.6	0.8	1.1		1.2
No. of farms	32	32	35		99

Table 16. Ratio of Custom Work to Home Farm Work by Operator's Age, 195 Farms, Chinju Area, 1970.

	Operator's age				Total or average
	under 30	31–40	41–50	over 51	
Rice thresher					
Custom work ratio	3.5	4.7	5.7	5.4	5.0
No. of farms	26	54	48	37	165
Barley thresher					
Custom work ratio	3.9	6.1	5.7	6.2	5.7
No. of farms	25	54	51	38	168
Motor tiller					
Custom work ratio	2.2	1.2	0.9	0.3	1.2
No. of farms	18	41	27	13	99

machinery can be used at least up to the so-called break-even point, where the unit cost curve intersects the price curve of capital service, and that less total investment will be required for farm mechanization—including investment in human capital.

According to Tables 15, 16 and 17, the rate of custom work is strongly but inversely associated with farm size, as we have already seen, with a minor exception in the motor tiller case. As regards age of operator, for the threshers there is no consistent difference in rate of custom work except that the under 30 age class does comparatively less custom work. In the case of the motor tiller, however, the rate is strongly but inversely related to age. Finally educational level and custom work rate are also inversely associated in both threshers, whereas in the case of the motor tiller the middle school graduates do relatively more custom work.

In summary, operators of less than 10 tanbo of land, with under 6 years of education, and above 30 years of age are the main source of machinery service supply in the case of the threshers, whereas operators of less than 10 tanbo but under 30 years of age and with 6 to 9 years' education are the main

Table 17. Ratio of Custom Work to Home Farm Work by Operator's Education Level, 195 Farms, Chinju Area, 1970.

	Operator's education in years			Total or average
	under 6	6–9	over 9	
Rice thresher				
Custom work ratio	6.2	4.1	3.1	5.0
No. of farms	87	40	38	165
Barley thresher				
Custom work ratio	6.6	5.5	3.5	5.7
No. of farms	96	37	35	168
Motor tiller				
Custom work ratio	1.3	1.6	0.8	1.2
No. of farms	42	25	32	99

Table 18. Ratio of Custom Work to Home Farm Work by Farm Size per Family Member, 195 Farms, Chinju Area, 1970.

	Farm size per family member			Total or average
	less than 2 tanbo	2.1–4.0	over 4.0	
Rice thresher				
Custom work ratio	7.3	3.0	2.7	5.0
No. of farms	78	64	23	165
Barley thresher				
Custom work ratio	8.1	3.8	2.5	5.7
No. of farms	80	67	21	168
Motor tiller				
Custom work ratio	1.5	0.7	1.3	1.2
No. of farms	49	32	18	99

source in the case of the motor tiller.

Farmers with more than 10 years education appear to do relatively less custom work in any case. Perhaps they are more interested in off-farm jobs in industry.

It is also interesting that the main suppliers of service of the newest, most complicated capital item, the motor tiller, are under 30 years of age with 6 to 9 years education. They have, perhaps, a larger capacity to learn machine operation, and have decided to devote themselves to farming as frontiersmen for innovating new farming methods.

Finally, Table 18 shows the rate of custom work by farm size per family member. In general, the smaller the farm size per family member, the more custom work the farmer does. More important, nearly half of the holders of each type of machinery have less than 2 tanbo of land per family member. (There is a similar relationship in terms of man-equivalent labor force.)

The implication is that with little land per family member, not all family members can be employed on the home farm and farm income to support family living is relatively small, so that they need some other job opportunity. However, "the price of the source of income streams from agricultural production is relatively high in traditional agriculture".[11] The objective of acquiring machines for doing custom work as an off-farm job is perhaps a strong inducement to saving and investment.

Summary and Conclusions

"It seems that the functions which the farm and nonfarm sectors have to perform in order for growth to occur appear to be totally interdependent. On the one hand, the farm sector should be able to release labor force for the industrial sector which, in turn, should be capable of absorbing it. The release of labor force, by and of itself, and the absorbing of it, by and of itself, are not sufficient conditions for economic development to take place. It is only if these conditions occur simultaneously that growth can result."[12]

The recent rapid expansion in the nonfarm sector in Korea, which is the leading sector of the nation's economic development, has induced a transfer of labor out of the farm sector. This, in turn, has caused the farm wage level to increase rapidly.

But agricultural productivity and aggregate production, and hence factor earnings, remain relatively unchanged. Farm work simplification is therefore urgently needed not only to offset the labor deficit, particularly in areas near economic development centres, but also to release more of the labor now used for the production of traditional farm products for employment in expanding industries—providing either nonfarm products or farm products whose income elasticities are relatively large. Thereby, productivity and factor returns can be increased and food supply capacity can be enlarged since the reduction in unit cost shifts the supply function to the right.

The simplification of farm work can be made possible mainly by the introduction to agriculture of truly modern production factors that are substitutes for farm labor, especially in periods of peak labor requirement. However, the high price of capital, small capital accumulation, and small farm size are apparently important barriers to farm mechanization. Unit production cost is likely to be high when these substitutes are adopted on individual farms.

The cooperative type of farm organization (such as the "moshavim") or the collective (such as the "kibbutzim"), developed in Israel, are often seriously advocated for farm mechanization in Korea. However, we must remember that these types of institutions are outgrowths of the specific and particular historical and social environment of the Israeli people.[13] Indeed, not even the rice variety bred by the IRRI, which made possible the green revolution in the South Asian countries, is directly adaptable to the different environment of Korea. He who advocates these types of farm organization perhaps really knows what is going on and what is good in other countries, but does he know why and how that is so, or does he know or try to know what is going on and what is good in our own rural society, that may be adaptable to the modern economic system?

Korean farmers will continue, as they have done in the past, to develop institutions that they find convenient or economical in their own situation. The custom-work system is a good example. It can be found everywhere in the world. And possibly most individual farms will eventually have their own farm machines, like the sewing machine in the household, once the farm economy is sufficiently improved. But the custom-work system can provide an inducement to saving and investment, and a great opportunity for creative rural youth, as innovators, to get off-farm work in our society where other off-farm job opportunities are few, and finally to get on the so-called agricultural ladder in our society where the leasing system is not legally permitted.

An alternative way to farm mechanization may be the farm machinery service station or centre. This institution may be better than the Israeli type of cooperative in the sense that less burden is involved in forming and administering it. However, this approach will require much more public investment or expenditure and will take away some opportunity of capital accumulation by the farm sector itself. Moreover, it would be likely to become monopolised, which would give rise to imperfect competition and bring about inefficiency in the farm sector.

Thus far we have assumed that new and better forms of labor substitutes are available. In fact, the very crucial necessary condition for farm mechanization is availability of machines that can reduce labor requirements in peak labor periods. A rice transplanter and a grain harvester must be developed before anything else. However, the supply of such machinery is not by itself sufficient; the related farm techniques must be adapted to mechanical farming, and the skills and technical knowledge for machinery operation must be disseminated, as is well illustrated in the case of the motor tiller.

In short, the supplier of the new and better production factors, including non-material capital, in a very real sense holds the key to farm mechanization, since whenever a new and improved form of technology has become available and its adoption has been believed profitable, our farmers have accepted it, using joint or individual ownership, for custom work or for work on their own home farms.

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[6] *Ibid.*

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FARM MECHANIZATION IN TAIWAN: ITS PROBLEMS AND RESEARCH NEEDS

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As a result of the successful completion of the four Four-Year Economic Development Plans, the aggregate output of crops, livestock, fisheries and forest products in 1968 almost tripled the 1950–1952 average and the pre-war peak level. The annual growth rate of agricultural output was 5.0 percent for 1953–1956, 4.2 percent for 1957–1960, 6.0 percent for 1961–1964, and 6.2 percent for 1965–1968, an annual average of 5.2 percent for the entire 16-year period.

The significant increase in agricultural production not only made it possible for Taiwan to meet the domestic food requirements of a population that grew from 8 millions in 1952 to over 14 millions in 1970, but also provided a substantial surplus for export. The increase of agricultural production boosted foreign exchange holdings from US$114 million in 1952 to US$376 million in 1970, through the export of sugar, rice, bananas, pineapples, tea, mushrooms, asparagus, fruits, vegetables, fishery products, forest products, and other primary and processed agricultural products.

The growth of agricultural product has been continuous and steady in the last twenty years. However, the pattern of Taiwan's agricultural development, as influenced by rapid industrial development since 1952, can be clearly divided into two periods: 1952 to 1964 and 1965 to 1968. Changes in the structure of output and input are shown in Table 1.

Agricultural output shown in Table 1 includes only crop and livestock production. It increased at a rate of 4.19 percent in the first period and 3.01 percent in the second period. Common crops constituted more than 50 percent of the total value of agricultural output, and livestock and poultry products about 20 percent, in the first period. However, they changed to 45 percent and 28 percent, respectively, in 1968.

A comparison of the growth patterns in these two periods indicates that the expansion in total agricultural output depended relatively more upon increase in labor input and in crop area in the first period, and more upon large increases in capital goods inputs in the later period. There were large increases in modern inputs such as chemical fertilizers, feeds, and implements in the period 1965–1968. Consequently, significant changes in the composition of the total input have taken place in Taiwan's agriculture in the past ten years. The capital inputs now constitute

Table 1. Average Annual Growth Rate of Output, Input and Productivity of Taiwan's Agriculture.

Item	Period I (1952–1964)	Period II (1965–1968)
	percent	percent
Total output	4.19	3.01
Total input	1.74	4.18
Crop area	0.80	0.19
Labor input	1.25	0.55
Chemical fertilizers	5.84	9.70
Feed input	4.83	15.68
Implements and depreciation of farm equipment and buildings	2.31	8.16
Multiple cropping	0.74	−0.20
Crop yield	3.33	1.40
Land productivity per hectare	4.15	2.62

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

Note: *Total output index* was computed from the average of annual physical quantities of agricultural production, including crops and livestock, with product prices in the base period 1950–1952 as weights. *Total input index* was computed by the same method. It includes such items as imputed rent on cultivated land area, labor input, chemical fertilizers, feeds, seeds, farm buildings, and tools, irrigation service and animal power. *Labor input* was measured in terms of working days. *Multiple cropping* was computed by dividing the total crop area by the cultivated land area. *Crop yield index* was computed by the average of per ha. yields of crops with the values of production as weights. *Land productivity per ha.* was estimated by dividing the total agricultural production in terms of 1950–1952 value by the total cultivated land area.

a greater contribution to the agricultural output.

Agricultural production in Taiwan has been diversified to take advantage of its labor surplus with a high land production capacity. It can be seen from Table 1 that the development pattern of agriculture in the first period was characterized by the fuller utilization of labor and land resources supplemented by working capital input. Owing to the rapid development of industry, at more than 14 percent per year in recent years, Taiwan's agriculture has experienced the phenomenon of labor shortage for the first time in its history.

The total employment of Taiwan rose from 3,558,000 in 1964 to 4,500,000 in 1969. The annual growth rate of employment was about 4.0 percent.

Manufacturing industry had the highest rate of increase, 9.5 percent per year; meanwhile, employment in agriculture actually decreased. A case study of labor mobility indicates that about 62.0 percent of the labor increase in the non-agricultural sector was contributed by the agricultural sector.[1] The total number of agricultural workers began to decline after 1965 at a rate of 4.2 percent per year.

The rapid rise in agricultural real wage rates has increased production costs in agriculture in recent years. Furthermore, the labor-intensive cultivation in agriculture in the past decade has caused agricultural labor productivity to increase much less rapidly than industrial labor productivity. Consequently, the spread between per capita income in agriculture and per capita non-agricultural income has widened.

The relatively low income and low labor productivity in agriculture have become current major agricultural policy issues in Taiwan. The unbalanced growth between the agricultural sector and the non-agricultural sector has influenced agricultural production, as well as prices and wages of the economy. Without any improvement of the basic agricultural structure and adjustment of agricultural production patterns, further transfer of resources from agriculture to industry will only retard the growth of agricultural output, and eventually national economic development will be greatly affected.

In view of the necessity of modernizing Taiwan's basic agricultural structure in order to accelerate its economic development, the Government of the Republic of China has initiated a new agricultural policy. Its main purposes are to increase farmers' income and agricultural labor productivity and improve the welfare of rural communities. One of the new agricultural policy measures is to expand the scale of farm business and encourage farm mechanization.

Table 2. Power Tillers and Draft Animals in Taiwan, 1954–69.

Year	Power Tillers						Draft Animals Total at year end
				Horsepower			
	Total at year end	Made locally	Imported	Under 5	5–8	Above 8	
	(number)	(per-cent)	(percent)	(per-cent)	(per-cent)	(per-cent)	(head)
1954	7	0	100.00	—	—	—	406,172
55	9	0	100.00	—	—	—	412,018
56	60	5.00	95.00	—	—	—	412,440
57	180	34.44	65.56	—	—	—	412,346
58	600	35.16	64.84	—	—	—	416,368
59	2,262	57.07	42.93	—	—	—	417,159
1960	3,708	46.17	53.83	34.87	38.59	26.54	417,122
61	5,313	41.05	58.95	26.71	45.66	27.63	414,208
62	7,504	46.74	53.26	21.60	49.95	28.45	405,056
63	9,079	51.90	48.10	19.23	53.52	27.25	389,448
64	10,201	57.04	42.96	17.67	50.91	31.42	379,073
65	12,213	63.15	36.85	15.88	50.52	33.60	370,370
66	14,272	68.46	31.54	14.28	49.37	36.35	360,294
67	17,240	73.80	26.20	13.13	42.52	44.35	337,873
68	21,153	78.61	21.39	11.60	35.15	53.25	324,221
69	24,640	81.73	18.27	10.79	30.96	58.25	306,287

Source: Department of Agriculture and Forestry, Provincial Government of Taiwan, The Republic of China.

Table 3. Major Agricultural Machines in Use in Taiwan, 1960–69.

Year	Power Sprayer	Hand Duster	Hand Sprayer	Rice Thresher	Pump	Grain Dryer
1960	317	10,803	104,150	177,338	8,378	—
61	966	10,337	115,699	181,693	10,114	—
62	804	9,517	125,899	184,244	11,678	—
63	1,028	12,764	139,439	193,772	19,728	—
64	2,949	15,822	147,954	203,329	28,654	—
65	4,489	13,558	161,506	205,784	32,107	—
66	6,123	16,788	166,817	194,247	35,301	—
67	9,734	21,886	180,780	204,337	42,330	210
68	12,901	19,121	180,477	201,706	49,310	470
69	14,791	22,421	181,576	198,504	52,037	1,699

Source: *Taiwan Agricultural Yearbook*, Department of Agriculture and Forestry, Provincial Government of Taiwan, The Republic of China.

Present Situation of Farm Mechanization

As early as 1952 a blueprint for a farm mechanization program was drawn up by the Joint Commission on Rural Reconstruction (JCRR), and it has been carried on ever since. However, it was not until the mid-1960s, when labor shortage was keenly felt in the rural area, that the program was put in full swing. The number of power tillers for land preparation is now increasing at the rate of around 4,000 units a year, and by the end of 1969 there were more than 24,000 power tillers in use in rural Taiwan.

According to a rough estimate, 40,000 more units are needed in the coming four years to cope with the problem of labor shortage. The increased use of power tillers has brought about an average yearly decrease of more than 10,000 head of draft animals in the past few years (Table 2).

At present, power tillers with 14 HP or above are popular among farmers who are trying to render hired service to other people in order to repay the loans they have obtained for their purchase. According to a recent survey, about 56 percent of the annual hours of operation of large-type power tillers was devoted to customers' service for gaining additional income.[2]

Besides power tillers, the numbers of other farm machines, such as power sprayers, threshers, dusters, and water pumps, are also on the increase, while the demand for grain dryers, rice transplanters, harvesting machines, etc., is steadily growing. The numbers of major agricultural machines in Taiwan are shown in Table 3.

In spite of the increasing demand for farm machinery, most farmers consider the prices of farm machines too high. Most owners of power tillers obtained limited bank loans at an average annual interest rate of 12.24 percent, as well as government subsidies, to purchase their machines.

Due to the urgent need for implementing the farm mechanization program in Taiwan, a four-year plan has been mapped out by the Government of the Republic of China. One of the most important steps to be taken is to lower the prices and improve the quality of farm machines manufactured locally. Within the four-year period, it is planned to extend 120,000 sets of farm machines. The power tiller will be the major machine, and the target number is set at 6,000 for the first year, 8,000 for the second

Table 4. Type and Number of Farm Machines to be Extended Under Four-Year Plan.

Type of Machine	First year	Second year	Third year	Fourth year	Total
Power tiller	6,000	8,000	11,000	15,000	40,000
Mist-blower	3,000	5,000	7,000	10,000	25,000
Power thresher	3,000	5,000	7,000	10,000	25,000
Power cultivator	300	500	1,000	3,000	4,800
Rice transplanter	300	1,000	2,500	5,000	8,800
Rice combine	50	150	500	1,000	1,700
Grain dryer	300	500	1,000	2,000	3,800
Power reaper	100	500	1,500	3,000	5,100
Sprinkler set	50	100	150	200	500
Peanut planter	100	500	1,500	2,500	4,600
Grass cutter	50	200	350	500	1,100
Total	13,250	21,450	33,500	52,200	120,400

year, 11,000 for the third year and 15,000 for the fourth year. The type and number of major farm machines to be extended under the four-year plan is shown in Table 4.

Current Problems of Farm Mechanization

The farm mechanization program to increase labor productivity is now being carried out steadily in Taiwan. In the course of implementing the program, many technical and socio-economic problems should be considered before any type of agricultural machinery is introduced on a large scale. In the transitory period from human or animal labor to machine power, many problems will be encountered. The following are the most important or difficult.

1. *Farm size and land fragmentation*

Taiwan is an island of 36,000 square kilometers. Of this area only around 900,000 hectares are cultivated land. With 877,000 farm households in Taiwan at present, the average size of farm is just a little more than one hectare. According to the agricultural sample census in 1966, 38 percent of Taiwan farms were of less than 0.5 hectare, 67 percent less than 1.0 hectare, and 82 percent less than 1.5 hectares. Only 11 percent of the farms had over 2.0 hectares of farm land.

An even worse problem is land fragmentation. There are no official statistics showing how serious the situation is, but it is generally agreed that a typical farm usually has more than three pieces of land scattered in different places.

This situation may affect the use of farm machinery in two ways. First, the fragmentation of land tends to cause waste of time, as farm machines have to be moved from one place to another. Second, the small farm size also limits the full use of power machines.

Even though the land situation may not be the most important limiting factor at present, when the power tiller is the dominant farm machine, the future introduction of large machines with greater horsepower will be difficult without further improvement in land distribution.

Natural conditions must also be considered in the promotion of farm machinery. Since agricultural production is primarily associated with land, and machine power is largely used in cultivating farm land, it is necessary to know something about the soil.

Generally speaking, most soils in Taiwan are of loamy texture, and sandy soils are generally confined to a limited area along the sea coast. The heavy soils of slate and mudstone parent materials seldom contain over 40 percent of clay particles. Therefore, the soils in Taiwan, with a few local exceptions, pose little or no problem to the utilization of farm machines. Although soil texture does not seem to be a technical barrier, yet the design of farm machines introduced from abroad has to be modified or strengthened in order to suit the local conditions.[3]

2. *Climate and crops*

Besides land, climate is probably the most important factor affecting the growth of crops. Situated in a sub-tropical zone, Taiwan's major crop is rice. As in most rice-growing countries in the Far East, farmers in Taiwan customarily grow rice in paddy fields, and transplanting from nursery bed to the rice field is necessary.

Rice may not be the most difficult crop to which to apply farm machinery. But when rice is planted in paddy fields some technical problems arise. First, the paddy field is usually covered with water, thereby making its ground so soft that it may not be able to support the kind of machine that is most efficient mechanically either in planting or in harvesting. Second, rice transplanting is a rather delicate operation. Rice seedlings require tender care and can not be handled easily by machines. That is probably the main reason why we have not, up to this time, found a practical and efficient rice-transplanting machine.

Limited by small farm size, Taiwan farmers are inclined to take advantage of the long growing season to grow as many crops as the climate permits. Thus the multiple-cropping index is one of the highest in the world.

Under their intensive cropping system, farmers grow one crop after another and practise relay-interplanting before the harvest of the previous crop. This intensive use of land leaves only a short interval between crops. Farmers need agricultural machines that are powerful enough to complete land preparation and planting within this short period of time.

On the other hand, because of the practice of interplanting, farmers also need compact machines that can be maneuvered between rows of crops.

All these tend to complicate the problem of farm mechanization in Taiwan.

3. *High price of machines and low purchasing power*

In almost all the surveys made in Taiwan, farmers have unanimously pointed out that high price—particularly of power tillers—prevents them from buying machines. In the earlier years of farm mechanization most farm machines were imported, and the sale price was always jacked up by a high import duty.

Since 1966 the Chinese Government has prohibited importing ready-made farm machines from foreign countries, with the purpose of protecting the local industry. But this measure has produced little or no effect on the machine price at the local market. The sale price for a 14-HP power tiller is NT$51,000, which is equivalent to US$1,275. When compared with the price in Japan, the power tiller price in Taiwan is about one third higher. According to calculations made by Kudo, the market price of a power tiller in Taiwan is 40 percent higher than in Japan, but there are more attachments to the Taiwan-made power tiller. The attachment for transporting passengers is very popular and has almost become standard equipment.[4]

While the price of a power tiller in Taiwan is higher than in Japan, the farm income level is lower. In recent years Japanese farmers have greatly benefited from the government support price for rice. During the same period, Taiwan farmers have suffered low farm income, attributed to increase of input prices—particularly wages—and a rather stable price of output.

The 1967 farm income survey showed average farm income of NT$23,578 and farm family income of NT$40,388.[5] More recent information does not show much improvement. According to farm record-keeping statistics, farm income in 1969 was NT$34,069 and farm family income was NT$47,948.[6]

From the above figures we can easily realize that without outside help or loans from financial institutions, it is definitely beyond the capability of the average Taiwan farmer to buy a farm machine which would cost him NT$50,000.

According to a survey conducted by the Taiwan Provincial Department of Agriculture and Forestry,[7] more than 86 percent of machine owners had to obtain loans from agricultural financing agencies. Because of the heavy dependence on borrowed money, the interest rate has become a problem. Except for a few large farm owners, who usually purchase farm machines with little credit help, most farmers interviewed voiced complaint about the high interest rates, which usually range from 9.0 percent to 11.76 percent per annum.

The high rate of interest is also a heavy burden to manufacturers if a large proportion of their capital is borrowed from banks.

4. *Lack of suitable farm machines*

Up to the present, the most popular farm machine in Taiwan is the power tiller. Dusters, sprayers, and water pumps are also common. In other words, the farm machines in use today are mainly for land preparation, pest control, and water pumping. Machines for other farm operations, such as seeding, transplanting, and fertilizer application are still lacking.

Particularly needed at this moment are rice transplanting and harvesting machines, as well as dryers for different crops. Rice transplanting usually takes 12 percent of the total labor used; harvesting take another 16 percent. Together, they account for 28 percent. With such a large amount of labor being employed in these two operations, it is very important to mechanize them in view of the ever increasing wage rate and the limited time between the first and second rice crops.

Although some kinds of transplanters and harvesting machines have been experimented with for some time, none of them has been found suitable and practical. Imported combines are either too heavy or are unsuitable for the tropical climate. Transplanting rice is a very delicate operation, and the transplanters under experimentation are far from practical. As to machines for other crops, the situation is even less satisfactory. Thus, intensive machine development is urgently needed.

5. *Importing vs. domestic production*

Whether to import machines or to manufacture them domestically is a problem faced by many developing countries that are ready to initiate a farm mechanization program. It is likely to be important, since it is closely related to the price problem previously discussed.

In the case of Taiwan, farm machines were first imported from other countries and then were made locally.

As early as in 1954, JCRR imported seven different makes and models of garden tractors from the United States. But the experimental result was not satisfactory.

In the following year, two power tillers were purchased from Japan. They were put to various tests and found very adaptable to the local situation.

This heralded the period of power tiller extension in Taiwan and led many local manufacturers to produce power tillers by copying the foreign models. However, owing to insufficient funds and lack of proper manufacturing techniques, all the local manufacturers except a few of the larger ones had either gone bankrupt or changed to making other products by the end of 1960.

On the other hand, two groups of Taiwan industrialists, in cooperation with Japanese agricultural machinery companies, set up two factories to produce power tillers with some parts imported. In 1966 another machine company also came into being and concentrated on assembling rather than manufacturing farm machines, including power tillers. In that same year the Chinese Government officially placed an import embargo on power tillers in order to encourage the local machine industry and to save foreign exchange.

Even with all these developments, Taiwan has not solved the problem of supplying farm machines at reasonable prices. Although the purpose of allowing more factories to produce farm machines is to encourage competition among them, competition so far has had very little effect. The three major manufacturers constitute an oligopolistic market, which tends to lessen the force of price competition. In addition, the smallness of the market also inhibits manufacturers' lowering their prices.

As shown in Table 5, the total capacity of the three major manufacturers is 7,700 power tillers a year. The total current demand in Taiwan is estimated at 4,000 units a year. The un-

Table 5. Production Capacity and Output of Three Major Agricultural Machinery Manufacturers in Taiwan.

Manufacturer	Date of establishment	Total employees	Power tillers	
			Capacity	Actual production
China Agricultural Machinery Company				
Taipei plant	1960	250	3,600	1,945
Hsintian plant	1968	200	200	—
New Taiwan Company	1961	326	3,600	1,670
Great Earth Company	1966	100	500	—

Source: Zyuro Kudo, *The Problems of Taiwan's Agricultural Mechanization*, JCRR Special Report, Taipei, 1970, p. 31 (in Chinese).

balance in demand and supply causes the manufacturers to produce at less than their optimum capacity and prevents their exploiting economies of scale.

There are a number of family-size machine shops engaging in the manufacture of farm machinery and implements. These small manufacturers usually do not have qualified engineers and modern quality control systems and therefore they cannot produce machinery of good quality. The larger manufacturers have taken advantage of cooperation with Japanese companies to improve their quality standards, but the progress has been rather slow.

6. *Type of ownership of farm machines*

Because farm size is small, the working capacity of power tillers or other kinds of farm machines often exceeds the actual requirements of individual farms. For example, a 14-HP power tiller can till at least 10 hectares of land each crop season. But as we have previously mentioned, the average farm size is just a little over one hectare, thus leaving nine tenths of the working capacity unused. On the other hand, the price of a power tiller is rather high, often beyond the average farmer's reach.

In view of the above, many voices have been raised as to the mode of owning farm machinery. At the present time, more than 90 percent of power tillers are owned by individual farmers and the rest are owned in a number of ways, such as cooperative ownership, cooperative operation, and ownership by a government agency or farmers' organization.

Judging from the predominance of individual ownership, it seems that Taiwan farmers prefer to own their own machines provided they can afford to pay for them. It is also believed that with individual ownership farmers will take good care of their machines. But since the farmers cannot keep their machines busy with their own farm operations, they have to offer service to others.

As previously mentioned, a survey made in 1969 found that about 56 percent of the operating time of power tillers was in such service. However, as the number of power tillers continues to grow, the market for hired service will become relatively narrower. Furthermore, as power tillers become larger and larger in horsepower, individual ownership will be more expensive.

This development tends to give rise to the following questions: Is individual ownership of power tillers best in terms of machine efficiency? In this connection, Taiwan is now encouraging farmers to purchase power tillers collectively and is also helping farmers' associations to organize farm machine service teams. But these developments are still under experimentation and there is no data for making comparisons and reaching definite conclusions.

7. *Mechanical knowledge of the farmers*

The average farmer in Taiwan lacks mechanical knowledge. This is not unusual in the early stage of farm mechanization, but it is one of the hindrances to the extension of farm machinery. It tends to hamper farm mechanization programs in two ways.

First, farmers are hesitant to adopt mechanical equipment for farm operation.

Second, if a machine develops any trouble, no matter how small, farmers are not able to fix it by themselves and have to bring in a technician from afar. This not only wastes time but also discourages farmers from using machinery.

Needed Research

Some of the problems that we have reviewed and discussed in the preceding pages can be solved by extension or education, some fall under government administration, but most of them require further research or experiment. In this section I discuss needs and priorities for research relating to farm mechanization. I have attempted to classify these needs by major categories based upon the ultimate purposes of the studies.

1. *Technical aspects.*

This category covers a wide area of possible research studies, but emphasis should be placed on developing the most suitable and efficient farm machines. This calls for a lot of field experimentation and engineering research, in which engineers, biologists, and economists as well as farmers should all be involved.

Since results of experiments at research institutes often are not applicable on farms, field experiments should be conducted at places where the field situation is most close to that on real farms. Furthermore, experiments should also be conducted on different cropping and management patterns. More specifically, this research can be further divided into the following three inter-dependent studies:

(1) Engineering research in connection with developing or modifying various farm machines, particularly power tillers, transplanters, harvesting machines and dryers.

(2) Field experimentation with farm machines of various types and horsepower.

(3) Experimentation on crop improvement and new crop systems made possible by the introduction of farm machines.

2. *Institutional aspects.*

As mentioned earlier, a farm mechanization program is not intended only for the introduction of farm machinery *per se*. It involves institutional change or adaptation. Under the conditions in densely populated developing countries and according to the experience of Taiwan, it is suggested that the following research studies are most needed:

(1) Comparative study on different types of machine ownership and on systems of custom work services.

(2) Impact and implications of farm mechanization on rural institutions, with special emphasis on land distribution and the tenure system.

(3) The role of institutional financing in the process of farm mechanization.

3. *Economic aspect.*

In developed countries like the United States, Canada, and Australia, farm mechanization came about without any government push behind the mechanization program. Farmers' adoption of machinery was largely motivated by the universal rule of profit maximization, because there were obvious advantages in replacing labor with machines.

The advantage in Taiwan is not so evident. From a macroeconomic point of view, farm mechanization is the only alternative; but from an individual farmer's viewpoint this alternative is not very attractive as far as economic profit is concerned. This is a rather puzzling situation.

Of course, the high price of farm machines may be responsible, but it is not the whole answer. It is likely that this problem is a result of the economic structure as a whole. Thus, it may be worthwhile to spend some time studying it.

On the micro level, there are many worthwhile and urgently needed studies. The most important ones, it seems to me, are the various substitution relationships among factors of production and the effects of farm machines on the farm business. Specifically, they are:

(1) The substitution relationship between labor and machine and between animal power and machine power.

(2) The substitution relationship between crops as a result of the introduction of farm machinery.

(3) The effect of farm mechanization on farm income.

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[6] Department of Agriculture and Forestry, Provincial Government of Taiwan, *Report of Farm Record-Keeping Families in Taiwan, 1969*, PDAF, 1970.

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FARM MANAGEMENT RESEARCH TO GUIDE DECISION-MAKING ON MECHANICAL INNOVATIONS

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This paper has three main objectives. One is to describe the long-run tendency and characteristic features of farm mechanization in Japan. The second is to discuss the characteristics of farm mechanization as mechanical innovation. Finally we consider the farmer's problem of decision making regarding investment in or replacement of machines.

Tendency, Effects and Characteristic Features of Farm Mechanization[1]

Long-run tendency

We can divide the farm mechanization process into four stages in Japan: the pre-war stage, the draft-animal stage (1945–55), the power tiller stage (1955–67), and the riding-tractor stage (since 1967).

During the pre-war stage, the initiator of farm mechanization was the landlord. Because land improvement was very effective for increasing rice yield, landlords began introducing power-pumps in the 1900s in order to increase the land rent. After 1930, landlords transferred their interest to introducing the power huller, because they could raise the land rent through the improvement of rice quality by its use.

Next came substitution of the power thresher for the pedal thresher. Small motors or engines were also distributed to farmers for threshing, hulling, milling, straw processing, etc., in the same period. Farmers were able to cut down the labor necessary for rice production and apply the saved labor to other enterprises to earn more income. Just before the war there were 180,000 power hullers and 360,000 threshers. The number owned by farmers reached 1,008,000 hullers and 3,297,000 threshers in 1967.

After land reform, the role of initiator of farm mechanization shifted from landlord to large-size owner-farmer.

An owner-farmer aims in principle, at the maximization of his farm household income and ultimately the total net utility of all family members, subject to the limitations of his family labor force and owned capital. In practice, farmers set up aspiration levels of living as income targets and endeavor to increase farm household income enough to satisfy this aspiration level of living.

Until 1955, in the draft-animal stage, the aspiration level was the landlords' living level within the rural community. But in the power tiller stage, with the progress of industrialization, the aspiration level shifted to the level of living of workers engaged in secondary or tertiary industries. Since 1960, urbanization of rural communities has been rapid, and farmers' aspiration levels have been rapidly driven up through the decentralization of industries and the demonstration effect of nonfarm workers' living levels. The rapid rise of farmers' aspiration levels for living expense and leisure has been the main incentive to drive farmers into farm mechanization.

A great many owner-farmers were established by the land reform. They worked very hard, following Arthur Young's precept that "ownership changes sand into gold," and accumulated capital enough to introduce technological innovations.

During the draft animal stage, their endeavor concentrated on biological innovations to raise income through the increase of rice yield. Since the early 1950s their effort has concentrated on switching over from draft animal to power tiller in order to raise land productivity through intensification of the rice enterprise as well as diversification of farming systems.

These owner-farmers' efforts burst forth to reap a rich harvest in 1955. Total rice production jumped up from 9 million tons to 12 million tons.

After 1960 farm labor began to flow out to the nonagricultural sectors. But labor-saving as well as yield-increasing innovations overcame the labor shortage and the decline of labor quality. Rice production jumped still further, to 14 million tons in 1967. This great increase in supply of rice was accompanied by a decline in demand for rice. It has resulted in a rice surplus problem in recent years.

The diffusion ratio of the power tiller stood at 3 percent at the end of the draft animal stage in 1955. It reached a peak of 55 percent at the end of the power tiller stage in 1967. The diffusion ratio of the riding tractor was 1.4 percent at the beginning of the tractor stage and is increasing rapidly now. It was 5.3 percent in 1970.

The most important effect of introducing the power tiller was to shorten the time necessary for cultivation and to make the growing period of rice earlier. It was supplemented by the development of excellent early-growing varieties and various improvements of protective practices, repeated fertilization, and careful water control.

However, systematic application of large-size machines has not been carried to completion in rice production, especially because the direct sowing technique has not been perfected and because profitable enterprise combinations are not available for solving weed and soil fertility problems.

If farmers introduce large-size machines, labor productivity will be increased but land productivity will be decreased. If land service and family labor are estimated on the basis of their opportunity return, the system of large machines can not match the system of small machines, because the opportunity return of the saved family labor is low while land rent is high.

When the riding tractor age started, the farmers' reactions were different from the government's large scale mechanization program. During the early 1960s, farmers thought that it was more effective to increase yield than to save labor in order to increase their farm income.

The agricultural machinery companies in Japan responded to the farmers' request to increase labor productivity without decreasing land productivity on small farms. They invented medium-size tractors, transplanters and combines. These domestic medium-size machines have tended to push up the size of farms or the size of land operated with the machines through such arrangements as joint use, custom work, or cooperative farms.

What type of cooperative use is reasonable or profitable? It depends upon the labor market situation and land layout conditions, especially the degree of water control by the individual farmer. Where nonfarm job opportunities are limited and each farmer can not control water individually, joint work and joint use of medium or large size machines will be prevalent. However, where nonfarm job opportunities are plentiful and land improvement allows farmers to control water individually, private ownership and custom work of machines will become prevalent. The most serious problem is how to increase the land size operated by viable farmers through the transfer of land ownership or cultivation from part-time farmers in order to promote larger-scale mechanization in accordance with the aggravation of labor shortage and the rise of farm wage level.

Mechanization and rice production

We have mentioned the remarkable increase in rice production and the accompanying decrease in labor requirement associated with introduction of the power tiller. The national average yield increased from 340 kg per 10 are in 1949–54 to 430 kg in 1955–65. Labor input per 10 are decreased from 201 hours to 168 hours over the same period. Moreover, year-to-year variation in yield was remarkably stabilized during 1955–65.

In considering these changes, however, we should not overlook closely associated biological and chemical innovations in rice farming. These innovations combined with mechanization to increase and stabilize the yield of rice after the war. First was the advancement of the growing period of rice so that typhoon and cool weather damage was avoided. Second was breeding, improvement of fertilization and water control, and more effective preventive chemicals. Third, land melioration and readjustment also played an important role.

Having said this, however, let us focus attention upon changes in labor inputs and in costs and returns in rice production, using national average data. According to the Surveys of Production Cost of Rice made by the Ministry of Agriculture, average labor input has consistently decreased as motive power input has increased, as shown in Table 1. Labor input per 10 are decreased from 205 hours in 1950 to 128 hours in 1969. During the same period, motive power input increased from 3.5 hours to 18.9 hours.

Table 1. Average Labor and Motive Power Inputs per 10 Are in Japanese Rice Production, 1950–69.

Year	Labor Input (hours)	Motive Power Input (hours)
1950	204.5	3.5
1956	183.2	5.1
1960	172.7	7.8
1965	141.2	14.6
1969	128.1	18.9

Source: Ministry of Agriculture and Forestry Surveys of Production Cost of Rice.

Let us examine the figures by operation. In cultivation, labor and motive power inputs amounted to 12.2 and 4.9 hours in 1969, whereas they were 23.1 and 0.4 in 1956. In threshing, the inputs were 10.3 and 3.0 hours in 1969, whereas they were 20.8 and 2.9 in 1956. In hulling, the inputs were 4.5 and 0.9 hours in 1969, whereas they were 6.0 and 0.9 in 1956.

Responding to the increase of nonfarm job opportunities and the rise of rice price since 1960, farmers applied mechanical and biological innovations with more investment in farm machines. Total production cost increased year by year because of the increase in rural wage levels, in spite of labor saving innovations.

The production cost per 150 kg of brown rice was Y 5,784 on an average farm in 1956. It went up to Y 15,622, that is, 2.7 times as high, in 1969.

Yield per 10 are was 402 kg in 1956. It increased gradually up to 502 kg in 1967 but then began to decrease and reached 484 kg in 1969.

Labor input per 10 are was 183.2 hours in 1956; it decreased continuously to 128.1 hours, a one-third reduction, by 1969. About 12 percent of total labor was hired during these 15 years. Average draft animal service was 11.8 hours in 1956. It was only 0.1 hours in 1969.

Let us examine the composition of production cost and returns. Labor cost amounted to 50.4 percent in 1956 and 52.2 percent in 1969. Fertilizer cost amounted to 21.2 percent and 11.2 percent.

Cost for machines and implements amounted to 7.1 percent and 18.0 percent. Draft animal service cost amounted to 9.6 percent in 1956 and 0.2 percent and 1969. These are average figures of 2,395 farms surveyed in 1956 and 4,062 farms in 1969.

The price of rice began to rise rapidly under the price support policy after 1960, and had doubled by 1968. Gross revenue per 10 are increased rapidly with the rise in price and increase in yield. Gross revenue from rice production per 10 are was ¥27,913 in 1956; it reached ¥67,778, more than twice as high, in 1969. Therefore, the net returns to family and operator's labor increased from ¥17,176 per 10 are and ¥838 per labor day in 1956 to a peak of ¥34,744 per 10 are and ¥2,440 per labor day in 1969.

In summary, the cost of machines and implements has increased while the cost of draft animals has decreased. The increase in cost of machine and implements has been more than compensated by the increase of nonfarm income earned by the saved labor and by the rise of the rice price since 1960.

Characteristic features of mechanization

As summarized above, mechanization was applied mainly in rice production before the war. But we should not neglect the rapid mechanization in other enterprises after the war. Secondly the degree of mechanization has been uneven among operations. Highly mechanized operations have coexisted with manual operations. Recently, use of the rice transplanter, binder, and medium-size combine has been rapidly increasing. The diffusion ratio of the transplanter is expected to be 30–40 percent and of the binder and combines 60–70 percent by 1975.

Such machines are specialized by operation and mostly have their own motive power. For example, the medium riding tractor is mainly used for plowing and to a small extent for transportation. Harrowing is done with a walking power tiller after storing water in the paddy field. Transplanting is done with a small walking transplanter. For protective operations, large power sprayers or small pipe dusters are used. Binders and medium-size combines are used for harvest. Various sizes of dryers, hullers and transport trucks are used.

As mentioned above, each operation is done with specialized machines, not with a riding tractor combined with various kinds of attachments. These machines are quite different in capacity of operation and only substitute for the several manual operations without changing the function and time of the operations.

Mechanization has helped reduce the seasonal variation of labor input and has released family workers from rice production. But such machines are idle much of the time because of small farm size. In Japan additional costs incurred by mechanization have exceeded the sum of the additional revenue from the same enterprise plus the opportunity returns which the saved family labor earns in other enterprises on an average farm. We call such a situation over-investment in machines.[2]

Finally we should mention the difference in mechanization between developed and underdeveloped areas and between large and small farms. Both differences have been gradually reduced since the war. Even among small farms with 50–70 ares of land 19 percent have power tillers, as do 39 percent of those within 70–100 ares. Labor productivity has been increasing with mechanization, while capital productivity has been rapidly decreasing on part-time farms. However, part-time farmers are subjectively apt to estimate the sum of opportunity return earned by the saved family labor and income equivalent of the utilities derived from leisure and machine display to neighbors as being greater than the estimated additional costs of machine depreciation, repairs and interest.

Farmers' motivations in buying machinery

In general, the economic objective of a family farm is to maximize the total net utility of family members subject to their limited amount of family labor and capital. Total net utility consists of positive utility of farm and nonfarm income and negative utility of family labor used in both activities. Therefore, if a farmer can expect to add more utility from the increase of income in other farm enterprises and in nonfarm activities or from additional leisure of family members than the utility lost because of the decrease of income in the rice enterprise, he will apply a mechanical innovation in his rice enterprise.

Moreover, family members seek utility from demonstration or display of newer machines to neighbors. Younger sons are so sensitive to this demonstration utility that their parents cannot help investing in more efficient but expensive machines in spite of overinvestment from the viewpoint of income.

As economic effects of farm mechanization, we can list that hired labor cost decreases and that family labor replaced with machines may be applied to other operations which need more careful manual labor or to other enterprises and nonfarm jobs. These opportunities bring additional income. Especially when the family members can find more stable job opportunities, the opportunity return will be enough to compensate for additional machine cost. Also, mechanization may increase yield, may improve quality of product, or may shift the harvest to a time when the price is higher. Some farmers may place high value on the release from heavy manual work and more leisure.

A survey of 87,000 farms by the Ministry of Agriculture in 1967 investigated the motives for adopting the riding tractor. The survey included 48,000 individual owners and 39,000 joint owners of riding tractors.[3]

Table 2. Motives for Substituting Riding Tractor for Power Tiller.

Motives	Individual owner	Joint owner
	%	%
Labor shortage	36.4	34.6
Making work easier	17.7	10.2
Enlarging farm size	10.7	9.7
Diversifying farm enterprises	3.7	6.4
Multipurpose use	5.9	2.7
Power tiller cannot do operations in time	7.6	6.9
Power of tiller insufficient	6.0	8.7
Save time for nonfarm job	1.6	2.7
Son's desire for riding tractor	7.1	4.1
Demonstration effect on neighboring farmers	0.2	1.9
Other	3.4	12.0
Total	100.0	100.0

Source: Takei, A., *Farm Mechanization in Japan*, Daimei-do, 1971, p. 52.

The motives for substituting a riding tractor for a power tiller were quite varied (see Table 2). The most important motive was to make up for labor shortage. The next was to make hard manual work easier. Others included enlarging the size of farm and replacing an inefficient power tiller. Farmers also bought tractors to make possible diversifying the enterprise system or enabling family members to take nonfarm jobs to meet rising living expenses. It is interesting that son's desire to get a riding tractor, or demonstration utility, is one of the important motives.

Farm Mechanization as Mechanical Innovation

The most important mechanical innovation has been the switchover from draft animal to power tiller. Inamoto has analyzed the shift of the rice production function resulting from the switchover from draft animal to power tiller in the Shonai area, Yamagata Prefecture.[4] He estimated the parameters of a Cobb-Douglas type production function from data of the *Survey of Production Cost of Rice* by the Ministry of Agriculture in 1956–61.

The Production function is as follows:

$$Y_t = A_t X_1^{\alpha_t} X_2^{\beta_t} e$$

symbols: Y_t: total production (kg)

X_1: land area (are)

X_2: costs of farm machines and draft animals (yen)

A_t, α_t, β_t: parameters

e: error term

t: level of technology represented by different methods of tillage

Land area represents labor input and costs of non-durable capital goods together with land service, because of multicollinearity.

He classified the farms surveyed in 1956–58 into two groups: (1) farms which use only draft animals (53 farms) and (2) farms which use power tillers together with draft animals (33 farms). He classified the farms surveyed in 1959–61 into three additional groups: (3) farms which use only draft animals (40 farms), (4) farms which use power tillers together with draft animals (30 farms), and (5) farms which use only power tillers (8 farms).

Table 3. Parameters of the Production Functions.

	A_t	α_t	β_t
Group 1	11.2	0.711*	0.269*
Group 2	2.6	0.785*	0.374*
Group 3	38.1	0.997*	0.027
Group 4	35.8	1.001*	0.029
Group 5	27.6	1.026*	0.046

* Significant at 1 percent level.

The estimated parameters for the production functions are shown in Table 3.

In each period, the switchover from draft animal to machine power was associated with increase in production, the larger part of which could be attributed to increase in inputs. However, we observe in each case an increase in the sum of the Cobb-Douglas exponents ($\alpha+\beta$), indicating increase in economies of scale. Furthermore, the relative increase in β, ($\Delta\beta/\beta$), was greater than in α, implying non-neutral innovation favorable to greater use of X_2 relative to X_1, i.e., to increase in durable capital goods (draft animals and farm machines) relative to land—a land (and labor) saving pattern.[5]

Machine Replacement Policy

The problems of deciding the most profitable durable life of a machine and the time when an old machine should be replaced by a new one have not yet been given much study in farm management research in Japan. More importance has been attached to comparing the relative profitability of draft animals and various types of machines.

Kudo has reported an economic study of the replacement of power tillers on Shonai farms.[6] According to his survey of 350 rice farms and 8 dealers located in the region in 1963, 31 percent of the farmers had replaced their old-type power tillers with improved new ones prior to 1963. The main reasons for replacement were: (1) They could increase labor efficiency by a new-type power tiller. It was rotary with a 7 or 9 horsepower gasoline engine, but the price was much the same as that of the old type with 4 or 6 horsepower. (2) Annual charges for repairs, maintenance, and lubrication of various implements were going up very rapidly as the tillers got older. (3) The price at which a farmer could sell an old tiller was going down sharply with its age, because of economic obsolescence of old-type power tillers.

Kudo concluded that the average useful life of a power tiller was 8 years in this region, but that a farmer should replace his old tiller every fifth year, for the above mentioned reasons.

Theory of machine replacement

The author has developed a decision-making model for investment in or replacement of machines.[7] Although this model has not yet been applied to practical empirical problems, it is presented here as of possible theoretical interest.

A family farm should transfer itself to a new subjective equilibrium point where the total net utility is maximized by adopting a mechanical innovation. We can substitute the maximization of enterpreneur's section of a family farm. The objective of investment in a new machine should then be to maximize the present value of entrepreneur's returns for the investment period.

The farmer can estimate all other productive factors which are combined with the service of the new machine and subtract their values from the gross revenue. Thus he can calculate the residual return to the machine service and his entrepreneur's service. Of course, every productive factor must be used to the limit where its marginal value productivity becomes equal to its price. Value of family labor and service of own capital is estimated subjectively. Account is taken of the difference between acquisition cost and salvage value of the machine.

Then we can express the present value of entrepreneur's returns by equation (1):

$$(1) \quad G = \sum_{t=1}^{T} \frac{Q_t}{(1+r)^t} + \frac{S_T}{(1+r)^T} - C_o$$

Symbols:

G: present value of entrepreneur's returns,

Q_t: return to the machine service and entrepreneur's service in the t-th year,

S_T : salvage value of the machine at the end of the T-th year, when it is sold,

C_o: value of capital investment in the machine,

r: interest rate on capital investment in the machine,

T: number of years the machine is used (life of machine).

First, we will explain the necessary condition of the most profitable amount of investment in the machine when the number of years' life, T, is fixed. As investment in the machine increases, the marginal increase of the present value of entrepreneur's returns, ΔG, may be increasing at first and later decreasing. When ΔG decreases to zero the total present value of entrepreneur's return, G, is maximized [equation (2)]:

$$(1)\quad \Delta G = \sum_{t=1}^{T}\frac{\Delta Q_t}{(1+r)^t}+\frac{\Delta S_T}{(1+r)^T}-\Delta C_o = 0$$

We can define the marginal internal rate of return to investment as

$$(3)\quad \Delta C_o = \sum_{t=1}^{T}\frac{\Delta Q_t}{(1+\rho)^t}+\frac{\Delta S_T}{(1+\rho)^T}$$

Then, we can interpret the necessary condition of G maximization as shown in equation (4):

$$(4)\quad \rho=r$$

It indicates that the investment in the machine should be increased to the limit where the marginal internal rate of return becomes equal to the rate of interest.

Secondly, we develop the necessary condition of the most profitable machine life. The value of the machine will decrease with use, natural deterioration, and economic obsolescence. The return to machine service and entrepreneur's service in the T-th year, Q_t, will decrease with extension of life of the machine, T.

If the farmer extends the years of use, he must take account of the opportunity cost of the entrepreneur's service in taking care of the machine for the extended year. That is to say, the object of investment would be to maximize the present value of entrepreneur's returns, H_t, earned by infinitely repeated investment in the same kind of machine, shown in equation (5):

$$(5)\quad H_T = G_T\left[1+\frac{1}{(1+r)^T}+\frac{1}{(1+r)^{2T}}+\ldots\right] = G_T\frac{(1+r)^T}{(1+r)^{T}-1}$$

Let us assume that the machine life, T, is discretely variable by year. The most profitable number of years, T, is that which satisfies the necessary conditions (6) and (7):

(6) $H_T \geqq H_{T-1}$

(7) $H_T > H_{T+1}$

Equations (8) and (9) are derived from (6) and (7):

(8) $H_{T-1}.r \leqq Q_T$

(9) $H_T r > Q_{T+1}$

Equation (8) implies that the additional return to investment in the T-th year, Q_T, must at least equal the opportunity cost of the additional entrepreneur's service, $H_{T-1}.r$, which is needed when the use of the machine is extended from the (T−1)-th year to the T-th year. We can interpret (9) similarly.

The additional opportunity cost of the entrepreneur's service is also called the time-adjusted entrepreneur's return per year.[8]

We can decide the most profitable replacement time of an old machine with a newer machine in the same way. Let the most profitable number of years of use for the newer machine be *u*. The present value of the infinite series of entrepreneur's returns is defined as shown in (10):

$$(10)\quad H_u = \left[\sum_{t=1}^{u} \frac{Q_t}{(1+r)^t} + \frac{S_u}{(1+r)^u} - C_o\right] \frac{(1+r)^u}{(1+r)^{u-1}}$$

We assume that the old machine is continued in use for *m* more years and then replaced with the newer one. Investment in the newer machine is infinitely repeated from that time on.

Then the present value of permanent entrepreneur's returns earned by the investment in the old machine and the infinite series of investments in the newer machine which substitutes for the old one after *m* years is defined in equation (11):

$$(11)\quad H_m = \sum_{t=1}^{m} \frac{Q_t}{(1+r)^t} + \frac{S_m}{(1+r)^m} - S_o + \frac{H_u}{(1+r)^m}$$

where S_o and S_m indicate salvage values of the old machine sold now or *m* years later. The value of the old machine is estimated by the salvage value S_o instead of the acquisition cost at the present time.

The replacement year *m* is chosen to maximize the present value of permanent entrepreneur's returns H_m. The necessary conditions are:

(12) $H_m \geqq H_{m-1}$

(13) $H_m > H_{m+1}$

from which

(14) $H_u \cdot r \leqq Q_m + S_m - S_{m-1}(1+r)$

(15) $H_u \cdot r > Q_{m+1} + S_{m+1} - S_m(1+r)$

In equation (14), Q_m and S_m indicate the return to the machine service and entrepreneur's service which is earned in the m-th year and the salvage value at the end of the year when the old machine is replaced. If the old machine is sold at the salvage value S_{m-1} at the end of the $(m-1)$-th year and the proceeds are deposited in a bank until the end of the m-th year, the sum of principal and interest amounts to $S_{m-1}(1+r)$. Therefore, the value $Q_m + S_m - S_{m-1}(1+r)$ is the additional return when the replacement time is extended one year from the end of the $(m-1)$-th year. The value $H_u \cdot r$ is the opportunity cost of the entrepreneur's service which is needed to extend one year.

Equations (14) and (15) imply that the additional return to the entrepreneur's service earned by extending one year from the $(m-1)$-th year must at least equal opportunity cost, and the additional return earned by extending one year from the m-th year must be smaller than the opportunity cost. The end of the m-th year from now is the most profitable replacement time provided m satisfies both necessary conditions.

SUMMARY

First, we observed the long term tendency of farm mechanization through the pre-war stage, draft animal stage, power tiller stage, and riding tractor stage. Secondly, we clarified the character and effect of farm mechanization in rice production. Thirdly, we described the characteristic features of farm mechanization subject to small farm size. In Japan, land has been the most scarce resource. Farm mechanization has advanced to the extent that labor productivity was increased without sacrificing land productivity. Fourthly, we discussed farmers' motivations for

mechanization. We then cited an analysis of the shift from draft animal to power tiller as a progressive innovation.

And finally we presented a theoretical model of decision making on investment and replacement of machines.

[1] Takei, A., *Farm Mechanization in Japan*, Daimeido, 1971. Yoshioka, K., *Mechanization of Japanese Agriculture*, Hakuyosha, 1939, and *Problems of Farm Mechanization*, Hakuyosha, 1941.

[2] Kayo, N., *Problems of Farm Mechanization in Japan*, Noseichosakai, 1962.

[3] Takei, *op. cit.*, pp. 48–54.

[4] Inamoto, S., "Technical Innovations and Scale Economies in Agriculture", in *Collections of the Papers of Modern Agricultural Science*, Yokendo, 1971.

[5] Using an adaptation of the method of Brown and Popkin ("A Measure of Technological Change and Returns to Scale," *Rev. of Econ. and Stat.*, 44: 402–31, 1962), Inamoto analyzed the components of the successive shifts as follows:

Effects on Production of Shifts from Use of Draft Animals to Use of Power Tillers, and Components.

Shift	Production increase ratio	Effect of input increase	Effect of innovation	
			Neutral	Non-neutral
		(percent)		
Group 1 to	76.1	55.9	10.7	9.5
group 2	(100.0)	(73.5)	(14.1)	(12.5)
Group 3 to	35.5	33.2	0.1	2.2
group 4	(100.0)	(93.5)	(0.3)	(6.2)
Group 4 to	6.2	4.9	0.3	1.1
group 5	(100.0)	(78.8)	(4.2)	(17.3)

He concluded that the innovations represented by the successive switchovers from draft animals to power tillers showed technological progress, the degree of progress being largest in the 1956–58 period, but slower in 1959–61.

[6] Kudo, Z., *Economic Study of the Replacement of Power-tillers on Shonai Farms*, The Bulletin of Tohoku Agri. Expt. Stat., Bul. No. 37, 1969. For additional details see his paper presented at this Workshop, p. 101.

[7] Yori, T., "Decision Making on Farm Investment", *Farm Accounting Research*, No. 5, 1971.

[8] Lutz, F. and V., *The Theory of the Investment of the Firm*, Princeton Univ. Press, 1951. Terbough, G., *Dynamic Equipment Policy*, McGraw Hill, 1949.

METHODOLOGIES USED FOR THE ANALYSIS OF FARM MECHANIZATION

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A tremendous number of research studies on farm mechanization have been made so far in Japan. Some of these have dealt with non-economic problems. However, much emphasis has been placed on economic analysis of introduction of farm machinery on individual or joint farms. The economic analyses made so far are classified into two major categories: positive analysis and normative analysis.

With this in mind, this paper attempts to review the principles used for these two kinds of analysis, and to make clear some related problems or limitations. Much emphasis is placed on the methodological presentation, which is considered to be applicable for every country where farm mechanization is in its beginning stage. Very simple examples or hypothetical models are used so as to make it easier to understand the basic principles. The methodologies presented here are limited to those which are widely used for the analysis of individual farms (micro level). The examples shown are studies made by Japanese research workers.

The paper is divided into four sections. The first section describes the scope and limitation of cost accounting analysis, one of the most conventional approaches to the study of farm machinery. The second section deals with the budgeting method. This is useful for analysing the total repercussion on farm organization caused by the introduction of machinery.

Mathematical tools of analysis are presented in the last two sections. Based on survey data for a large number of farms, we can determine the marginal value of productivities of resources, including machinery, and the optimum combination of the resources (e.g. labor and machines), using marginal analysis. This is presented in the third section. Finally, the linear programming method is used for the problem of introduction of farm machinery on an individual farm. Two examples are given. The first case is the analysis of the total effects on farm organization caused by the machinery introduced. The second case is the determination of the optimum farm plan with the purchase of machinery. To modify the divisibility assumption used in this method, the integer linear programming method is briefly discussed. These programming methods are presented in the fourth section.

Cost Accounting Study

In the cost accounting study, we usually compare the economic advantage or profitability of the machinery with that of draft animals or sometimes hand labor. This is because machinery is being introduced on farms as an alternative or substitute for draft animals.

To make the comparison, the cost function is ordinarily applied. In many cases, the concept of average cost is used. The most typical analysis is to sum up the fixed and variable costs incurred per unit of land operated. The comparison of total per unit average cost is made between draft animal and farm machinery. In so doing, we can determine which is more advantageous or obtain the break-even point between using animals or machinery.

In Figure 1, the vertical axis shows the average cost incurred per unit of land and the horizontal axis indicates the total acreage plowed. The fixed cost curve usually has an asymptotic shape, while the variable cost curve is a straight line running parallel with the horizontal axis. Accordingly, the total cost curve is of asymptotic type. The slope and height of the asymptotic curve are different for draft animals than for farm machinery. In this Figure, A is the break-even point where the total cost curves for draft cattle and for farm machinery intersect. This means that the introduction of machinery is profitable for a farmer if his acreage plowed is greater than E, but it is more advisable for him to use a draft animal if his total acreage plowed is less than E. Needless to mention, E is the equilibrium point between these two alternative methods of plowing. This is the basic principle of cost accounting analysis for determining the optimum practice.

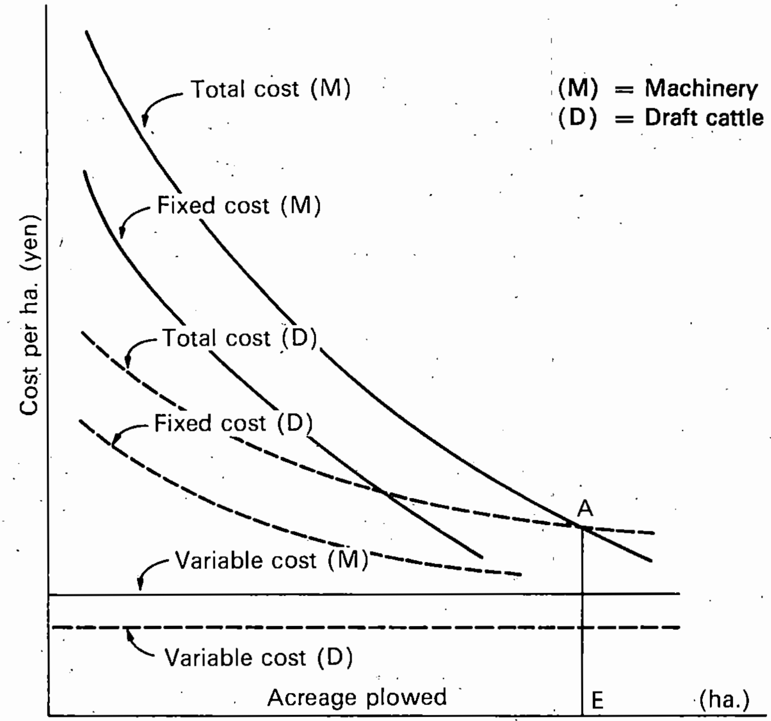

Fig. 1. Comparison of Total Costs per Hectare Between Draft Cattle and Machinery.

In some cases, the comparison is between costs of machinery and of hired labor. The principle applied is almost the same as that for draft cattle. Ordinarily, the hired labor cost is regarded merely as a variable cost. Therefore, the point where the total cost curve of machinery and the variable cost curve of hired labor cross becomes the break-even point.

Usually, the investment in a machine means that average cost is high for small acreage plowed and gradually decreases as the acreage increases. Whether machinery use is more profitable than hand or animal labor depends partly on the conditions under which machinery is introduced, and partly on the method of cost accounting. Suppose a farmer owns neither farm machinery nor a draft animal and plans to introduce machinery or an animal on his farm. Then he must consider all the costs incurred. He has to include as fixed cost the interest on investment, taxes assessed, insurance and depreciation, etc. The fuel and oil cost or the feed cost are variable costs. However, if a farmer already possesses a cow and keeps her for fattening even after introducing a machine, the fixed and variable costs of animal power must be changed accordingly.

Now there is another problem of how to account the costs, or how to evaluate non-cash costs such as unpaid family labor. Depreciation cost of farm machinery is the major item of fixed cost. But this varies greatly with the number of years the machine is used. There is a set formula table indicating the duration in years for each kind of machinery. This table, however, is worked out primarily for the purpose of taxation, and does not necessarily show the actual condition under which a machine is being used.

Moreover, the life of machinery varies with intensity of use. The period shown in the standard life table is based on average operation. Suppose a farmer possesses a power tiller and its life is five years when used for 10 hectares, the average and normal type of operation in a year. If he uses it for 20 hectares of paddy field, it is unreasonable to count five years as the length of life for his equipment. It is also irrational to count fifty years in the case in which the machine is used for only one hectare every year.

The next problem is how to evaluate the non-cash items. This is especially important in case of a family farm for which almost all the labor is provided by the farm operator and his family. The cost of unpaid family labor varies with the imputed wages. Usually, the wage paid for hired labor is used.

This evaluation method seems rational when there are many employment opportunities outside the farm. However, a problem arises when, for example, a draft animal is kept by family labor for which no employment opportunity outside the farm is available. If we evaluate the cost of family labor used for keeping an animal at the wage rate for hired labor, we may draw the somewhat surprising conclusion that it is more advantageous to use machinery rather than to use an animal even for a small scale of operation. This is because the cost of maintaining the animal by family labor is counted as a fixed cost and this is estimated at the high wage rate for hired labor.

The next problem is that in comparing machine and draft animals, we do not take the maximum (or optimum) size of operation into consideration. There are maximum levels of operation for which a machine or a draft animal can be used. It is not feasible, for example, to use only one unit of power tiller or draft cattle for plowing 10 hectares of paddy field. Even if it were possible physically, it is still impossible from the viewpoint of "the work at the proper time". This means that the plowing season in each area is fixed biologically, say a week or ten days long. Therefore, we can not use a power tiller two weeks for plowing 10 hectares of land. This is also true for using a draft animal.

In spite of this, it is usual to compare the total costs incurred in the use of a machine or a draft animal under the assumption that these are applicable beyond the maximum or optimum size of operation. To make the cost accounting analysis more accurate, we have to draw a stepped cost function. A drastic change in the total cost or a discrete shift to a new cost curve takes place at the point of maximum size of operation.

The final problem is that we simply compare the total costs incurred in the use of machinery and in the use of an animal under the assumption that they are independent of other factors. We do not consider the total profit and loss in the whole farm organization which are caused by the introduction of the machinery.

Budgeting Analysis

The magnitude and type of profit and loss depend on particular conditions on the farm on which the machine or animal is introduced. A profit and loss statement or balance sheet provides a better basis for determining the relative advantage of a machine or draft animal. Specifically, the budgeting method is more useful for this kind of analysis.

The general form of profit and loss statement used for budgeting analysis is as follows:

Extra costs	A	Costs saved	C
Profit foregone	B	Extra profits	D
	A + B		C + D
	A + B + E		C + D

In this balance sheet, E is a measure of the advantage of the change which has been dealt with in the calculation. In greater detail, the following items are included in each of the categories, A, B, C and D:

A: Fixed and variable costs incurred in operation of the machine; costs incurred in expanded or newly introduced farm enterprises.

B: Decrease in profit caused by farm enterprises foregone.

C: Decrease in costs incurred in farm enterprises foregone; decrease in the cost paid for hired labor or in the cost for unpaid family labor.

D: Receipts from custom work; revenue from newly adopted enterprises; additional revenue caused by increase in yields of farm enterprises.

In such a balance sheet we consider the total (direct and indirect) effects of newly introduced machinery on the farm organization. Using this analytical method, we can compare in advance more elaborately the profitability of the introduction of machinery on a farm. This forward-looking analysis is called farm planning. The conventional method of farm planning is budgeting analysis.

There are two major categories of this analytical tool, partial and complete budgeting. Partial budgeting refers to estimating the outcome or returns for a small part of the farm. Complete budgeting refers to making out a plan for the whole farm organization.

The following is a simple example of partial budgeting analysis made by Mr. Yoshio Hayashi about twenty years ago. Table 1 shows the cost accounting of machinery and draft cattle. Next, he worked out the balance sheet using partial budgeting analysis. This is shown in Table 2.

From these tables, we can see that there are significant changes in labor requirements. In sowing suguki, a winter vegetable crop, four more hired workers are required when plowing is done by draft cattle than when plowing is done by machine. Consequently, the total expense incurred in sowing suguki is 2,163 yen using draft cattle and 1,473 yen using machine. In sowing wheat, on the other hand, the draft animal is more advantageous. In total, however, machinery use proves to be more profitable for growing of winter crops.

Table 1. Cost Accounting of Machinery and Draft Animal.

(Unit: yen)

Item	Power cultivator	Draft cow
Fixed costs:		
Depreciation	12,000	800
Interest	9,000	350
Tax	680	—
Total	21,680	1,150
Total per 0.1 ha.*	867	115
Variable costs:		
Total per 0.1 ha.**	206	48
Grand total per 0.1 ha.	1,073	163

Source: Yoshio Hayashi, "Doryoku Kounki no Donyu (Introduction of Power Tiller into a Farm)", *Nogyo to Keisai (Agriculture and Economy)*, 21 (6), 1953.

* Total acreages plowed by machinery and animal are estimated as 2.5 ha. and 1 ha., respectively.

** Sum of miscellaneous, repair and feed costs.

He analysed in further detail another aspect of the advantage of the introduction of machinery. The gross revenue from suguki varies greatly with its marketing period. The price realized from suguki sold in December is 40 percent higher than in January, the price in February 50 percent lower. In order to sell suguki in December, a farmer has to finish sowing it by early September at the latest. But harvesting of rice must be done during the same period. The plowing and sowing following immediately after the rice harvesting can be done more quickly by machine. Thus we can see an additional advantage of using a power tiller in this vegetable growing area from the viewpoint of marketing strategy.

Marginal Analysis

As mentioned previously, the concept commonly used for cost

Table 2. Partial Budgeting for 0.1 ha. of Work.

Crops	Type of work		Labor input		Costs incurred		Total (yen)
			total	hired (day)	hired	plowing*	
Suguki	animal	(A)	8	5	2,000	163	2,163
	machine	(B)	4	1	400	1,073	1,473
	(A) – (B)		4	4	1,600	–910	690
Wheat	animal	(A)	5	2	800	163	963
	machine	(B)	3	0	0	1,073	1,073
	(A) – (B)		2	2	800	–910	–110

Source: Yoshio Hayashi, *ibid.*

* Costs are shown in Table 1.

accounting analysis is the average fixed and variable costs. In addition to these, there is another concept widely used for economic analysis: the marginal cost theory. Here is an example of marginal analysis applied to farm mechanization. This was done by Tadashi Tenma, based on survey data of 343 upland farms in Kanagawa Prefecture. The following Cobb-Douglas type of production function was derived:

$$\log y = \underset{}{0.728} + \underset{(0.046)}{0.382} \log x_1 + \underset{(0.053)}{0.151} \log x_2 + \underset{(0.013)}{0.017} \log x_3$$

$$+ \underset{(0.016)}{0.080} \log x_4 + \underset{(0.028)}{0.379} \log x_5$$

$\overline{R^2} = 0.768, \quad S = 1.249$

Sum of elasticities: 1.009

where,

y: gross farm receipts (1,000 yen)

x_1: land and buildings (10,000 yen)

x_2: labor (0.1 man equivalent (M.E.))

x_3: machinery (10,000 yen)

x_4: livestock (10,000 yen)

x_5: cash expenses (1,000 yen)

Table 3. Simple Correlation Coefficients Between Factors.

	Y	X_1	X_2	X_3	X_4	X_5
Y	1.000					
X_1	0.687	1.000				
X_2	0.348	0.248	1.000			
X_3	0.480	0.465	0.211	1.000		
X_4	0.573	0.302	0.287	0.215	1.000	
X_5	0.829	0.604	0.276	0.490	0.566	1.000

Source: Tadashi Tenma, "Farm Management Analysis of Ayase-Machi, Japan", *Bulletin of the National Institute of Agricultural Sciences*, H29, 1963.

Now, we can compare the marginal value of product and opportunity cost for each input resource. The marginal value of product of x is derived from the following equation:

$$\frac{\partial y}{\partial x_i} = b_i \frac{y}{x_i}$$

where b_i is the parameter of x_i in the above-mentioned production function. On the other hand, the opportunity cost is the market price prevailing in the area. For example, the market price of land has always been taken as the annual cost of renting per unit of land. The employment of additional labor would imply the purchase of hired labor, as the wages paid for hired labor is the opportunity cost for labor input. The comparison between the marginal value of product and the opportunity cost of each input resource is shown in Table 4.

The ratios of A/B in the table show the measure of the efficiency of resource use. If the ratio is less (greater) than unity, it indicates the too much (too little) of the particular resource is being used under the existing opportunity cost. Maximum efficiency in resource use is attainable when the marginal revenue from one additional unit of input is equal to the cost of an additional unit. In other words, this occurs when the ratio of marginal product to opportunity cost is equal to one. More specifically, the optimum amount of y to be produced is defined by the following equation:

$$\frac{\mathrm{MVP}_{x_1}}{\mathrm{P}_{x_1}} = \frac{\mathrm{MVP}_{x_2}}{\mathrm{P}_{x_2}} = \cdots = \frac{\mathrm{MVP}_{x_n}}{\mathrm{P}_{x_n}} = 1$$

From the ratios of marginal return to opportunity cost shown in Table 4 the existence of resource use disequilibria is evident. Especially is this true for land and labor. This means that the average farmer could have increased profits substantially by expanding his land and reducing the labor input. Also, it can be seen that excessive machinery services were being used, or added machinery investment would likely contribute less to production on these farms than actual cost of the machinery services.

Next, Tenma calculated the marginal rate of substitution between labor and machinery. In general, the marginal rate of substitution refers to the absolute change in one input associated

Table 4. Marginal Value Product and Opportunity Cost of Each Input and Ratio of Marginal Return to Opportunity Cost.

Input		Unit of measurement	Geometric mean	Marginal value product (A)	Opportunity cost (B)	Ratio of marginal return to opportunity cost (A/B)
				(yen)	(yen)	
Land and buildings	X_1	¥10,000	167.900	990	530	1.868
Labor	X_2	0.1 M.E.	19.860	3,298	10,800	0.306
Machinery	X_3	¥10,000	5.698	1,280	2,700	0.474
Livestock	X_4	¥10,000	3.932	8,820	2,110	4.180
Cash expenses	X_5	¥1,000	132.240	1,245	1,050	1.186

Source: Tadashi Tenma, *ibid.*

with a change of one unit in a competing input. The marginal rate of substitution between labor (x_2) and machinery (x_3) is derived as follows:

$$\frac{\partial x_2}{\partial x_3}=\frac{b_3 x_2}{b_2 x_3}=k\frac{x_2}{x_3}$$

Now, substituting the geometric means of each factor except for x_2 and x_3 in the estimated function:

$$2.638=0.728+0.382\,(2.225)+0.151\,(\log x_2)+0.017\,(\log x_3)$$
$$+0.080\,(0.595)+0.379\,(2.121)$$

the following iso-quant curve is derived:

$$\log x_2=\frac{0.209-0.017\log x_3}{0.151}$$

Substituting the values of x_3 in the above equation, the values shown in column (2) of table 5 are obtained. The values of column

Table 5. Marginal Rate of Substitution of Machinery for Labor Derived from Cobb-Douglas Function Model in Ayase-Machi, 1959.

Machinery and labor to produce average output of ¥434,280		M.E. replaced by additional expenditure of ¥10,000 for machinery
machinery (¥10,000) (1)	M.E. (man) (2)	(3)
2	2.210	0.125
3	2.143	0.081
4	2.079	0.059
5	2.017	0.046
6	1.985	0.037
7	1.950	0.032
8	1.926	0.027
9	1.897	0.024
10	1.869	0.021
11	1.840	0.019
12	1.840	0.017
13	1.812	0.016

Source: Tadashi Tenma, *ibid*. The original result was revised by the author.

(3) are computed using the previously mentioned equation of marginal rate of substitution.

It is generally said that if the cost of additional machinery service is less than that of the labor replaced by the machinery, additional input of machinery is profitable. Accordingly, replacing 0.125 man-equivalent with 10,000 yen of machinery (line 1 in the table) would be advantageous because the labor opportunity cost of 13,500 yen ($0.125 \times 108{,}000$) is greater than 2,700 yen, the (annual) opportunity cost of additional input of 10,000 yen of machinery. (The opportunity cost of machinery is the total of depreciation, repair costs and interest.) Under this condition, the equilibrium point of substitution between x_2 (labor) and x_3 (machinery) is where 90,000 yen of machinery is equivalent to 1.897 man-equivalents. If the opportunity cost of labor increases and the machinery cost stays at the same level of 2,700 yen, the optimizing condition would require that more labor be replaced by machinery. For example, if the wage rate per year becomes 171,000 yen instead of 108,000 the optimum combination of these two resources is 130,000 yen of machinery and 1.812 man-equivalents.

Linear Programming Method

One of the most effective tools for the analysis of the introduction of farm machinery is linear programming. Using this method we can analyse more precisely the total effects on farm organization caused by introducing a machine.

In general, the primary effect of introducing machinery on a farm is, needless to mention, the saving of labor. If the labor saved is hired labor, as a matter of fact, the economic effect is the wages previously paid.

However, if it is unpaid family labor, the saved labor itself is not so meaningful unless it brings forth some economic effects on the farm. For example, if the saved labor makes it possible to adopt double cropping or to introduce a more profitable new enterprise, and thus to increase farm revenue, it can be said that the saved labor brings about a positive effect on farm organization.

With linear programming we can present to a farmer the normative pattern of production to be followed so as to maximize his farm revenue. Using this method, we can take account of the total effects caused by the introduction of farm machinery. A case in point is the study of a diversified farm made by Tomio Kikumoto about ten years ago. Basic data on his programming are shown in Table 6. Next, the simplex tableau worked out for the analysis of the introduction of machinery is shown in Table 7.

In Table 7, Δ-activity shows changes in the farm organization. For example, the coefficient -5, at the intersection between column P_1 and row P_7, means that five days of labor would be released for the spring work on paddy field by the introduction of farm machinery. A negative sign indicates the output or supply of resource per unit of the specified activity. A positive sign means the input or demand for resource per unit of the specified activity.

The zero price of P_1 indicates that no change in the yield of rice is anticipated from introducing machinery. If there were an increase in rice yield, a positive value of price would be seen in the P_1 activity. As a result, 850 yen $(250 \times 4 - 150 \times 1 - 100 \times 0)$ is shown as the net profit of P_1 in the table. The objective function is to maximize the following equation:

$$Z = 850x_1 + 100x_2 + 7{,}500x_3 + 38{,}100x_4 + 550x_5 - 5{,}950x_6 - 50{,}760 \rightarrow \text{Max.}$$

The coefficient 50,760 is, as shown in table 6, the depreciation (or fixed) cost of machinery to be deducted from the total revenue.

The optimum solution obtained is $x_4 = 0.08$ (ha.), $x_5 = 71.0$ (ha.) and $Z = 394.6$ (1,000 yen). However, the actual plan is $x_3 = 0.13$ (ha.), $x_4 = 0.06$ (ha.), $x_5 = 6.0$ (ha.) and $Z = 40.1$ (1,000 yen). The remarkable difference between the optimum and actual plans is the level of custom work. In actuality, it is impossible to do 71 ha. of custom work during the short period of transplanting. From the analytical result, it might be concluded that barley grown on paddy in the winter season is not profitable, and that as much custom work should be done as possible so as to lessen the machinery cost. Furthermore, Kikumoto pointed out that the so-called over-investment in farm machinery can be recognized even for such a comparatively large-scale farm.

Finally, the modified method of linear programming applicable

Table 6. Basic Data on Programming.

1) Size of farm:
   - Paddy field: 3.05 ha. (1.0 ha. of double cropping is available)
   - Upland field: 2.30 ha. (1.0 ha. is used for growing of cash crop)

2) Saved labor caused by introduction of power cultivator:
   - Paddy field: 5 days per 0.1 ha. provided by family labor (spring)
   - Upland field: 2 days per 0.1 ha. provided by family labor (fall)
   - Paddy field: 4 days per 0.1 ha. provided by hired labor (spring)
   - Upland field: 1 day per 0.1 ha. provided by hired labor (spring)
   - Wages paid for hired labor is 250 yen per day.

3) Machinery cost:
   - Operation cost: 350 yen per 0.1 ha.
   - Hauling cost: 100 yen per 0.1 ha. (incurred only for custom work)
   - Depreciation cost: 50,760 yen.

4) Increase in production:

Crops	Acreages ha.	Spring Labor days/0.1 ha.	Fall labor days/0.1 ha.	Revenue 1,000 yen
Barley	0.13	5	5	7.650
Tobacco	0.06	20	80	38.250
Custom Work	6.00	0.2	—	0.800
5) Decrease in production:				
Rape seed	0.50	10	—	5.950

Source: Tomio Kikumoto, "Doryoko Kounki no Linear Programming (A Study of Introduction of Power Tiller Using Linear Programming)", *Nogyo to Keizai (Agriculture and Economy)*, 26 (6), 1960.

Table 7. Simplex Tableau for the Analysis.

Resources		Δ-activity		Real activity		Idle activity		Resource restriction
		P_1	P_2	P_3	P_4	P_5	P_6	
Spring labor	P_7	−5		5	20	0.2	−10	—
Fall labor	P_8		−2	5	60			—
Paddy field	P_9	1						30.5
Paddy field (for double crop)	P_{10}			1				10.0
Upland field	P_{11}		1					23.0
Upland field (for cash crops)	P_{12}				1		1	10.0
250 Hired labor		−4	−1					
150 Operation cost		1	1	1	1	1		
100 Hauling cost						1		
	Σ	−850	−100	150	150	250		
Price		—	—	7,650	38,250	800	−5,950	
Net price		850	100	7,500	38,100	550	−5,950	

Source: Tomio Kikumoto, *ibid*.

P_1 : paddy field, P_2 : upland field, P_3 : barley, P_4 : tobacco, P_5 : custom work, P_6 : rape seed.

to the analysis of farm mechanization is to be discussed. One of the limitations in the basic assumption of the linear programming method is that resources and products are considered to be infinitely divisible. This specifies that activities can be produced at the level of 3.75 cows, or 1.25 ha. of rice, etc. Of course, there are many resources or products in agriculture which can be used or produced in fractional amounts. A case in point is fertilizer input or level of crop grown on a fractional unit of land. However, it is unreasonable or impossible to introduce 3.75 cows, or 0.75 unit of power tiller, etc.

In order to overcome this limitation, we can apply the integer linear programming method. Using this technique, we can determine the optimum plan with integer levels of activities. There are two kinds of integer linear programming, pure and mixed programming. The former deals with the problem in which all the activities including slack variables must be at integer levels. The problem in the latter is that the levels of some of the activities (or any particular activity) must be at integer values.

Taking the example of two activities and three restrictions, the problem in the ordinary form of linear programming is to determine the optimum point within the feasible region OABCD in Figure 2. Suppose PP′ is the iso-revenue line of two activities, the optimum solution is the corner point C. The feasible region for pure integer linear programming is the set consisting of the lattice points (x marks) which are on the integer coordinates. On the other hand, the feasible region for mixed programming is the points which are on the segments HG, IF, JE and OA in Figure 3.

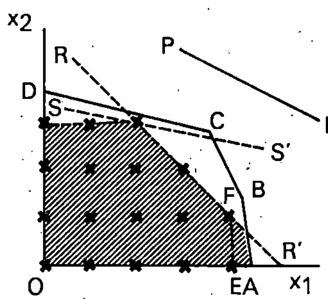

Fig. 2. Feasible Region for Pure Integer Programming.

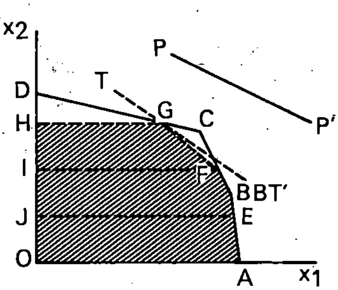

Fig. 3. Feasible Region for Mixed Integer Programming.

To find the optimum point, we have to impose additional constraints upon the feasible region. These are the lines RR′ and SS′ in Figure 2, and TT′ in Figure 3. (This can be done after solving the ordinary form of linear programming.) Now, the optimum point shifts from C to G. The algorithms for determining the additional constraint(s) or cutting plane(s) are presented by R.E. Gomory and others.[1]

The simple problem of the ordinary form of linear programming is shown in Table 8. The optimum level of the purchase of machinery is the fractional unit 0.640. Therefore, the additional

Table 8. Simplex Tableau for Ordinary Form of Linear Programming.

		15.000	5.500	7.000	−2.000
C_j (10,000 yen)		P_1	P_2	P_3	P_4
Resources					
Upland 6.5 (ha.)	P_5	1	1	1	
Spring labor 16.0 (10 hrs.)	P_6	5	2	1.5	
Fall labor 16.0 (10 hrs.)	P_7	8.5	2.5	3.5	
Machinery service 1 – (days)	P_8	3			−30
Machinery service 11 – (days)	P_9		3	4	−30

		33.067	2.566	0.067	0.500	2.067
$Z_j - C_j$			P_1	P_9	P_3	P_7
	P_5	0.100	−2.400	0.000	−0.400	−0.400
	P_6	3.200	−1.800	0.000	−1.300	−0.800
	P_4	0.640	0.567	−0.033	0.100	0.067
	P_8	19.200	20.000	−1.000	3.000	2.000
	P_2	6.400	3.400	0.000	1.400	0.400

P_1 : vegetable I
P_2 : vegetable II
P_3 : vegetable III
P_4 : machinery bought

The lower tableau shows the final stage.

Table 9. Simplex Tableau for Integer Form of Linear Programming. (Initial Stage)

		P_1	P_9	P_3	P_7
P_5	0.100	−2.400	0.000	−0.400	−0.400
P_6	3.200	−1.800	0.000	−1.300	−0.800
P_4	0.640	0.567	−0.033	0.100	0.067
P_8	19.200	20.000	−1.000	3.000	2.000
P_2	6.400	3.400	0.000	1.400	0.400
S_1	−1.000	−0.886	−0.091	−0.156	−0.105

Table 10. Simplex Tableau for Integer Form of Linear Programming. (Final Stage)

		P_7	P_9	P_3	S_1
P_5	0.382	−0.118	−0.141	0.024	−4.235
P_6	3.412	−0.588	−0.106	−0.983	−3.176
P_1	0.118	0.118	−0.059	0.176	−1.765
P_8	29.647	−0.353	0.176	−0.529	35.294
P_2	6.000	0.000	0.200	0.800	6.000
P_4	1.000	0.000	0.000	0.000	1.000

constraint S_1 is included in the final stage of the ordinary form of linear programming. This is shown in Table 9. Finally, Table 10 shows the optimum solution for the integer linear programming. Under the plan, one unit of farm machinery should be purchased exactly, and the total value of the objective function decreases from 33.067 to 32.765 (10,000 yen).[2]

Summary

The scope and limitations of the methodologies which are widely used for the economic analysis of farm mechanization are briefly discussed in this paper. Each method has its own strong points as well as limitations. We have to select the most suitable method according to the purpose of our analysis. It

seems unlikely that we can always obtain the best result by using the most elaborate method. Moreover, these methodologies are complementary rather than alternative to one another.

Many people believe that scientific methods can be applicable only in the advanced countries. Yet, as W.Y. Yang pointed out, "there is concrete evidence that even in places where the majority of farmers are illiterate, farm management survey, farm book-keeping and cost accounting and many other research techniques can be successfully applied."

[1] Gomory, R.E., "Outline of an Algorithm for Integer Solutions to Linear Programs", *Bul. Amer. Math. Soc.*, 64, 1958.
Land, A.H., and A.G. Doig, "An Automatic Method of Solving Discrete Programming Problems", *Econometrica*, 28(3), 1960.
Dantzig, G.B., "On the Significance of Solving Linear Programming Problems with Some Integer Variables", *Econometrica*, 28(1), 1960.

[2] The coefficients on the row of additional constraint (S_1), as shown in Table 9, are calculated by the following general formula:

$$\sum_{j=1}^{n} (-h_{ij})x_j + s_i = -1$$

where the x_j's are non-basis activities and s_i is the non-negative slack activity for the additional constraint. Next, the h_{ij}'s, the newly calculated coefficients on the row of additional constraint (S_1), are defined as follows:

if $\bar{a}_{ij} \geq 0$, $\quad h_{ij} = \bar{a}_{ij}/f_{io}$

if $\bar{a}_{ij} < 0$, $\quad h_{ij} = -\bar{a}_{ij}/(1-\bar{f}_{io})$

where the $\bar{a}_{ij}$'s are the coefficients of non-basis activities on the row of j-th activity which is introduced into the basis in the final stage and its level introduced is now changed into integer value, and $\bar{f}_{io}$ is the coefficient of the j-th activity in the basis. In the present case, the value of $\bar{f}_{io}$ is 0.640.

ANALYSIS OF MACHINERY-LABOR RELATIONSHIP IN FARM MECHANIZATION

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In Taiwan the need for adjustments in agricultural production and resource use has come under scrutiny in the past few years. The Joint Commission on Rural Reconstruction (JCRR) has undertaken a long-range research project on the change in agricultural structure in Taiwan, under the direction of T.H. Lee, Chief of the Rural Economics Division. It is a timely attempt to identify problems and possible solutions.

The present problems of low income and low labor productivity in agriculture seem to be rooted in the size of land holdings and the composition of inputs.[1] These two causes, however, result from the past policies of even distribution of landholdings and encouragement of labor-intensive farming systems.[2] These policies brought stabilization to the society and progress in agricultural production, which in turn accelerated general economic development. Nevertheless, farm mechanization is one adjustment for which no definitive actions have been taken and no results have yet been released.

The present adjustment is intended to modernize the agricultural sector to keep it in step with the other sectors of the economy.[3] For agriculture to play its appropriate role in the economy, two goals must be pursued. A moving adjustment in agriculture is required because of the interdependence between agriculture and the rest of the economy as the national economy grows progressively wealthier. And farming must become more efficient through advance in technology. The adoption of farm machines is one means to obtain the service of advanced technology.

The interdependence between agriculture and the rest of the economy requires agricultural adjustment on two fronts. On the demand side, the mix of agricultural products must adjust to changes indicated by income and price elasticities. On the supply side, the adjustment in agriculture has far-reaching implications for firms and organizations supplying farmers with goods and services and marketing farm products.

The purpose of this paper is to discuss the adjustment of farm labor utilization in the adoption of farm machinery. The question to be answered is whether the adoption of farm machinery is an additional investment in agriculture, so that labor transfer will be retarded by the high incomes received in agriculture, or whether it is a substitution of capital for scarce farm labor needed for the optimal combination of resources, so that norms of economic efficiency in resource productivities will be achieved.

Development of Mechanization in Taiwan

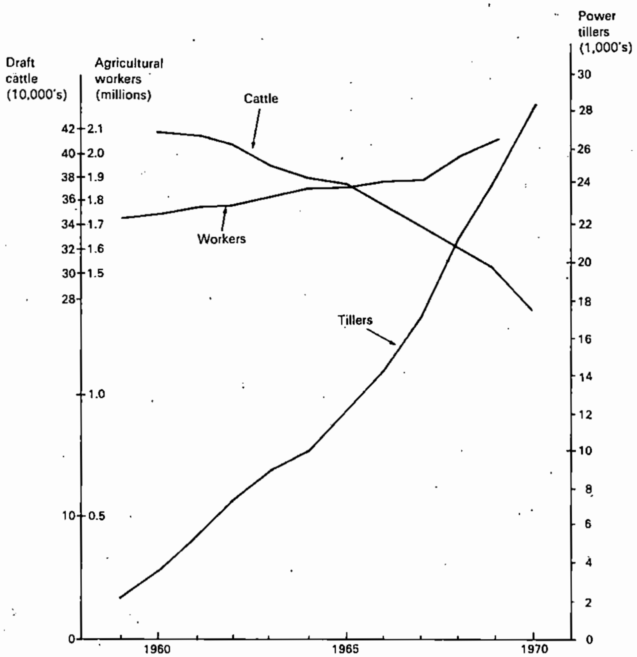
Mechanization in agriculture has different meanings to different people at various stages of economic and agricultural development.[4] In Taiwan, the movement started with the importing of power tillers in 1953, followed by domestic production of them in 1956 and establishment of seven promotion centers in 1958 to expand the adoption of power tillers over the whole island. The development can be divided into three stages, reflecting changes in perception and emphasis regarding the role of machinery in farming.

Stage One

During 1953–60, mechanization meant the substitution of power tillers for draft cattle. The machines were of 2 or 3 horsepower, with the brand names *Merry Tiller* and *Iron Cow*.[5] The background in this period, according to Lai's analysis in 1960, was that a shortage of draft cattle was predicted due to the low reproduction rate of cows (25 percent). He concluded that from the farmer's point of view it was uneconomical to raise draft cattle, and from the viewpoint of society it was too expensive to use land and labor for raising cattle instead of cultivating food crops.[6] The mechanization movement was to encourage the adoption of power tillers for land preparation. The energy used on Taiwan farms was thus to shift from man plus animal to man plus machine and implements.

In subsequent years the number of power tillers increased from 2,262 at the end of 1959 to 28,292 at the end of 1970, while the number of draft cattle decreased from about 417,000 to around 300,000 (Figure 1). During this period the power machines that increased in number most rapidly were pumps and power sprayers. Grain dryers began to come into use in 1967. (Detailed data are shown in the paper by Y.T. Wang, Tables 1 and 2, pages 219, 221). The changing demand for machinery reflected changes in technical conditions of production, in factor-product price ratios, and in the level of fixed factors of production.

Fig. 1. Numbers of Agricultural Workers, Draft Cattle, and Power Tillers, Taiwan, 1959–70.



Source: *Taiwan Agricultural Yearbook,* Provincial Dept. of Agriculture and Forestry, 1960–69 (see Table 1 in paper by Y.T. Wang, p. 219) and Table 2, below.

Stage Two

During 1965–69, mechanization entered a new stage emphasizing substitution of more powerful tillers (15 HP) for human labor on farms. Because the adoption of power tillers was mostly influenced by manufacturers' sales promotion, there was a pause for breaking through the problems encountered in mechanized rice cultivation.[7] Tiller owners sought efficient use of their machines by doing custom work for others and using them for transportation. This development, in turn, led to the adoption of more powerful machines (see again Wang, Table 2).

Had economic condition remained unchanged, the number of power tillers owned by farmers might have remained at around 10,000. However, the economic structure of Taiwan had changed during the three Four-Year Economic Plans from predominantly agricultural to one in which agriculture and industry shared equally important roles. Hence a shortage of farm labor developed. The seasonal index of farm labor requirements (Table 1) shows that this was most acute in July and November, followed by August and October. This was due to the small variation in cultivation patterns between the southern and northern parts of Taiwan. The shortage of labor in July and November, when harvesting and cultivation overlap, could be overcome only by introducing efficient machines to reduce the peak labor demand.

A study by Lin and Chen shows the radical change in the pattern of off-farm employment by farm family members from 1963 to 1968. The proportion of persons commuting regularly to work at salaried jobs increased from 25.9 to 47.9 percent, that of persons leaving home rather permanently to work in cities or other places increased from 17.3 to 26.0 percent.[8] Thus the proportion taking only seasonal off-farm work dropped from 56.8 to 26.1 percent.[9] Moreover, the proportion of the seasonal workers who took farm work decreased from 80 to 55 percent. This change resulted in a shortage of farm laborers during the harvesting and transplanting seasons. To make matters worse, the workers leaving agriculture consisted mainly of those under 39 years of age, especially male workers under 19. This has intensified the interest in mechanization.

Table 1. Labor Requirements Per Household, Taiwan, Monthly, 1960–69.

Unit: Man-Day

Month \ Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Average	Seasonal Index
1	53.57	44.27	42.22	38.39	36.75	40.08	44.68	46.22	43.45	39.22	42.88	90.77
2	57.80	38.36	35.49	40.53	34.56	38.25	42.00	40.13	40.47	35.22	40.28	85.27
3	59.56	51.85	50.31	53.34	45.36	45.95	46.32	48.63	49.45	39.60	49.04	103.81
4	50.06	43.89	41.02	48.49	39.61	40.10	41.23	45.13	51.44	37.46	43.84	92.80
5	54.44	45.91	43.30	45.90	35.88	39.89	46.10	48.11	45.38	38.99	44.39	93.97
6	59.20	46.80	40.21	46.60	37.50	39.16	46.46	45.42	45.83	39.33	44.65	94.52
7	73.13	64.79	65.68	65.96	54.91	57.14	58.88	60.96	67.31	57.08	62.58	132.47
8	54.53	51.60	53.95	58.19	42.96	45.50	47.69	49.54	58.41	46.13	50.85	107.64
9	52.86	36.30	44.51	40.56	37.92	41.08	47.49	46.20	45.34	34.04	42.63	90.24
10	63.47	50.11	50.62	52.17	44.14	45.88	54.64	52.76	50.69	42.59	50.71	107.35
11	63.77	56.98	58.67	58.68	47.14	48.73	51.19	51.38	52.60	45.53	53.47	113.19
12	50.82	42.57	45.82	42.88	33.28	36.55	41.89	41.73	45.57	34.34	41.55	87.96
Total or average	693.21	573.43	571.80	591.69	490.01	518.31	568.57	576.21	595.94	489.53	47.24	100.00
No. of Sample Farms	95	207	223	277	535	501	430	402	415	411		

Source: *Report of Farm Record-Keeping Families in Taiwan,* Annual, 1960–69, Dept. of Agriculture and Forestry, Provincial Govt. of Taiwan.

Stage Three

As a consequence of these developments, mechanization has now come to mean a machine-power oriented, capital-intensive way of farming. This corresponds to Chancellor's view that in the change from traditional to technological agriculture in the developing countries farmers have been energy starved. Tractors have been used not only for preparation of land but also for transportation and for irrigation pumping—both essential operations with a high energy requirement. The farmer's need of tractor energy was first for replacing his draft animals, then for implements for planting, intertillage, harvesting, and processing.[10]

Taiwan has reached a stage in which operation of the farm business needs the advantage of as much machine power as possible. Hence, items such as hand-wheel transplanting machines, power cultivators, and combines are being imported from Japan and demonstrated on farms. The results are not yet wholly satisfactory.

In sum, the rate of farm mechanization in Taiwan has fluctuated. When the demand for machines has been met by the supply, mechanization has moved forward, as in stage one and stage two. However, when the demand for machines has not been fulfilled by the supply, i.e. because of the lack of machines other than the power tiller, mechanization has halted. This was the case between stage one and two, and is again the problem today.

In the future, mechanization must be extended beyond the power tiller to all aspects of farm operations. A mission sent to study Japanese experience in agricultural mechanization concluded that in Japan the demand induced the supply and both cooperated and supported each other, and as a result the Japanese experience provided an excellent example in mechanization of rice cultivation.[11] This was said ten years ago, but it still fits the situation at the present moment for the development of mechanization in Taiwan in the near future.

Up to now, the improvement of farming in Taiwan has mainly been based on biological innovation rather than on mechanical innovation. As shown in Table 2, the ratio of fixed capital to

Table 2. Capital Inputs, Labor Inputs and Their Ratios, Taiwan, 1952–69.

Unit: Millions of $NT in 1952 Prices

Years	Capital Inputs			Labor Inputs		
	Working Capital (1)	Fixed Capital* (2)	Total (3)	Agricultural Workers (1,000's) (4)	Man-days (Millions) (5)	Total Wages (6)
1952	1,388.3	310.7	1,699.0	1,734.7	231.9	2,087.5
53	1,577.2	322.9	1,900.1	1,754.2	236.5	2,128.8
54	1,764.9	323.9	2,088.8	1,753.8	235.7	2,121.3
55	1.732.1	318.5	2,050.6	1,737.1	232.3	2,090.6
56	1,869.9	324.3	2,194.2	1,718.2	240.3	2,162.5
57	2,018.1	329.9	2,348.0	1,709.9	258.3	2,325.1
58	2,141.3	333.7	2,475.0	1,704.6	264.4	2,379.3
59	2,124.9	322.0	2,446.9	1,739.0	262.2	2,360.2
60	2,104.3	321.3	2,425.6	1,754.7	258.4	2,325.3
61	2,411.7	320.9	2,732.6	1,780.9	261.1	2,349.5
62	2,456.5	330.0	2,786.5	1,800.4	260.6	2,345.8
63	2,444.0	318.3	2,762.3	1,833.5	268.9	2,420.2
64	2,840.7	327.8	3,168.5	1,860.9	277.2	2,494.9
65	2,886.3	346.8	3,233.1	1,866.8	295.5	2,659.2
66	3,230.6	347.1	3,577.7	1,897.2	304.0	2,736.4
67	3,578.4	354.9	3,933.3	1,904.4	302.4	2,721.7
68	4,100.9	378.1	4,479.0	1,997.1	303.9	2,735.1
69	4,334.8	369.1	4,703.9	2,075.7	299.1	2,691.9

Years	Capital-Labor Ratio (7) = (1)/(4)	(8) = (2)/(4)	(9) = (3)/(4)	(10) = (1)/(6)	(11) = (2)/(6)	(12) = (3)/(6)
1952	0.80	0.18	0.98	0.67	0.15	0.81
53	0.90	0.18	1.08	0.74	0.15	0.89
54	1.01	0.18	1.19	0.83	0.15	0.98
55	1.00	0.18	1.18	0.83	0.15	0.98
56	1.09	0.19	1.28	0.86	0.15	1.01
57	1.18	0.19	1.37	0.87	0.14	1.01
58	1.26	0.19	1.45	0.90	0.14	1.04
59	1.22	0.19	1.41	0.90	0.14	1.04
60	1.20	0.18	1.38	0.90	0.14	1.04
61	1.35	0.18	1.53	1.03	0.14	1.17
62	1.36	0.18	1.54	1.05	0.14	1.19
63	1.33	0.17	1.50	1.01	0.13	1.14
64	1.53	0.18	1.70	1.14	0.13	1.27
65	1.55	0.19	1.73	1.08	0.13	1.21
66	1.70	0.18	1.88	1.18	0.13	1.31
67	1.88	0.19	2.07	1.31	0.13	1.44
68	2.05	0.19	2.24	1.50	0.14	1.64
69	2.09	0.18	2.27	1.61	0.14	1.75

Source: Provided and prepared by Miss Y. E. Chen, Rural Economics Division, JCRR, Taipei, May, 1971.

* Fixed capital includes expenditures for draft cattle, farm implements and machinery, depreciation of farm buildings, and water resources. Expenditures for farm implements and machinery include purchases of small implements and depreciation of large implements and machinery.

Table 3. Machine-Labor Substitution in Rice Cultivation in Taiwan (weighted averages for Ponlai and native varieties).

Item / Year	Soil Preparation			Fertilizing			Harvesting			Transporting			Others			Total		
	Man (Labor)	Animal (Labor)	Machine (hr.)	Man (Labor)	Animal (Labor)	Machine (hr.)	Man (Labor)	Animal (Labor)	Machine (hr.)	Man (Labor)	Animal (Labor)	Machine (hr.)	Man (Labor)	Animal (Labor)	Machine (hr.)	Man (Labor)	Animal (Labor)	Machine (hr.)
First Rice Crop																		
1969	9.0	6.7	7.3	7.2	0.2	—	16.7	0.3	—	2.2	0.2	—	48.8	—	—	105.8	7.4	7.3
1968	9.2	7.5	6.8	6.5	0.4	—	21.2	0.2	—	0.9	0.5	0.1	47.1	0.4	—	107.9	9.0	6.9
1967	10.7	8.1	4.6	5.8	0.2	—	18.6	0.4	0.1	1.2	0.4	—	49.3	0.7	0.2	110.0	9.8	4.9
Average	9.6	7.4	6.3	6.5	0.2	—	18.8	0.3	0.0	1.5	0.4	0.0	48.4	0.4	0.1	107.9	8.7	6.4
1961	16.8	13.9	—	5.9	—	—	16.6	0.2	—	—	—	—	38.6	0.1	—	104.0	14.2	—
1936–37	19.9	15.2	—	6.5	0.9	—	25.7	0.5	—	—	—	—	25.8	0.9	—	104.6	17.6	—
Average	18.3	14.5	—	6.2	0.5	—	21.2	0.3	—	—	—	—	32.2	0.5	—	104.3	15.9	—
Second Rice Crop																		
1969	7.7	6.5	7.5	7.4	0.3	—	16.4	0.4	0.1	0.7	0.1	0.1	46.1	0.3	0.1	98.8	7.6	7.8
1968	8.7	8.0	4.8	5.9	0.4	0.1	18.5	0.2	—	0.3	0.2	0.8	48.0	—	0.1	104.6	8.8	5.8
1967	11.1	8.5	3.0	6.1	0.2	—	18.1	0.2	—	0.7	0.2	—	48.2	—	0.1	109.3	9.1	3.1
Average	9.1	7.7	5.1	6.5	0.3	0.0	17.7	0.3	0.1	0.6	0.1	0.3	47.4	0.1	0.1	104.2	8.5	5.6
1961	13.1	11.1	—	4.1	—	—	17.2	0.2	—	—	—	—	46.6	0.2	—	106.9	11.5	—
1936–37	14.5	10.9	—	3.5	0.1	—	27.7	0.8	—	—	—	—	22.1	0.6	—	90.4	12.5	—
Average	13.8	11.0	—	3.8	0.1	—	22.5	0.5	—	—	—	—	34.3	0.4	—	98.7	12.0	—

Table 3. Machine-Labor Substitution in Rice Cultivation in Taiwan (weighted averages for Ponlai and native varieties).

Item / Year	Soil Preparation			Fertilizing			Harvesting			Transporting			Others			Total		
	Man (Labor)	Animal (Labor)	Machine (hr.)	Man (Labor)	Animal (Labor)	Machine (hr.)	Man (Labor)	Animal (Labor)	Machine (hr.)	Man (Labor)	Animal (Labor)	Machine (hr.)	Man (Labor)	Animal (Labor)	Machine (hr.)	Man (Labor)	Animal (Labor)	Machine (hr.)
Average																		
1969	8.3	6.6	7.4	7.3	0.2	—	16.5	0.3	0.1	1.4	0.2	0.1	47.4	0.2	0.1	102.1	7.5	7.7
1968	8.9	7.7	5.8	6.2	0.4	—	19.8	0.2	—	0.6	0.3	0.4	47.5	0.2	0.1	106.1	8.8	6.3
1967	10.9	8.3	3.8	5.9	0.2	—	18.4	0.3	0.1	0.9	0.3	—	48.7	0.4	0.2	109.6	9.5	4.1
Average	9.4	7.5	5.6	6.5	0.3	—	18.2	0.3	0.1	1.0	0.3	0.2	47.8	0.2	0.1	105.9	8.6	6.0
1961	14.9	12.5	—	5.0	—	—	16.9	0.2	—	—	—	—	42.6	0.2	—	105.4	12.9	—
1936–37	17.2	13.0	—	5.0	0.5	—	26.7	0.6	—	—	—	—	23.9	0.8	—	97.4	15.0	—
Average	16.5	12.7	—	5.0	0.3	—	21.8	0.4	—	—	—	—	33.3	0.5	—	101.4	14.0	—

Sources: 1. *An Economic Analysis of Rice Farms in Taiwan*, Taiwan Study Series No. 72, Economics Institute of Bank of Taiwan, Sept. 1959, pp. 105, 127 and 128.

2. *Statistics of Crop Cultivation Survey in Taiwan*, Department of Research and Experiment, Land Bank of Taiwan, Aug. 1962.

3. *Report on the Investigation of Farm Production Costs in Taiwan*, 1967, 1968 and 1969, Dept. of Agriculture and Forestry, Taiwan.

labor has been rather stable, whether per person or per dollar's worth of labor (columns 8 and 11), while that of working capital has increased (columns 7 and 10).[12] The impact of mechanization on production is still a thing of the future. In terms of Herlemann and Stamer's stages of "technification" of agriculture, progress in farm production techniques in Taiwan has passed from the biological technology or intensification stage toward the mechanical technology or mechanization stage.

Capital-Labor Relationship in Farm Operation

Substitution between inputs in farm operation is widely studied in production economics. In Taiwan, due to the limited land resources, the substitution of capital in the form of fertilizer for land has more than twenty years' history.

Substitution of capital in the form of farm machinery such as the power tiller for labor is really a new phenomenon, because farm labor has usually been redundant. However, certain industrial firms have reported a shortage of labor and have demanded more. The consequent transfer of workers symbolizes the mobility of labor among sectors and firms to achieve a more efficient allocation of labor in the development of the economy. It should be considered a welcome challenge to make the developing island of Taiwan dynamically in gear with the world economy.[13]

Regarding the substitution of machinery for farm labor, three questions have to be considered: (1) Will the substitution make the operation of the farm business more efficient?[14] (2) Will it improve the farmers' income position and make it comparable to that in non-farm sectors?[15] (3) Will it stabilize at certain levels?[16]

Technology and relative prices of resources determine the ratio of their substitution for labor on farms. In Taiwan, inputs other than farm labor have changed greatly over time, as shown by statistical data. Farmers have adjusted the resource mix, shifting from resources that were more expensive to those that were less expensive.[17] The change of farm-labor wage rates indicates the change in relative prices of farm labor and machines, since prices of the latter have not changed over long periods of time.

Table 4. Comparisons Between Draft Cattle and Power Tillers in Cultivation of Rice, with Calculation of Costs and Receipts.

Sources	Items	Power tiller (A)	Animal-Man (B)
Labor Requirement		(man-day/ha.)	(man-day/ha.)
I	Land preparation	4.6	10.48
	Transportation of manure	0.9	2.05
	Transportation of products	1.4	1.88
	Total (1)	6.9	14.41
II	Man-labor (2)	58.68	59.35
	Animal-man (3)	1.64	4.37
	First rice land preparation	2.44	11.45
	Second rice land preparation	2.42	11.25
III	First rice total (4)	101.48	116.47
	Man-labor	96.55	105.13
	Animal-man	0.87	11.34
	Machine hours	4.06	–
	Second rice total (5)	94.35	111.58
	Man-labor	90.02	100.22
	Animal-man	0.79	11.14
	Machine hours	3.54	0.22
Costs and Receipts			
I	Annual costs per household (6)	9,778.65	5,952.38
	Annual receipts per household (7)	11,759.45	4,921.61
II	Annual costs per household (8)	14,893.00	7,549.00
	Annual receipts per household (9)	15,688.00	4,758.00
Net Benefits			
I	(i) Man-days saved (1) (B) – (A)	7.42	0
	(ii) Cost saving (7) – (6)	1,980.80	–1,030.77
II	(i) Man-days saved (2) (B) – (A)	0.67	0
	(ii) Animal-man days saved (3) (B) – (A)	2.73	0
	(iii) Cost saving (9) – (8)	+795.00	–2,791.00
III	Man-days saved		
	First rice total (4) (B) – (A)	14.99	0
	Second rice total (5) (B) – (A)	17.23	0

Sources: Sections I, II and III in this table refer to three of the empirical studies cited later in this paper (pages 282–84). Where original labor figures were given in man-hours, conversion has been made on a basis of 8 hours per day.

What has been the impact of mechanization on the farm over the past 18 years? Data on machine-labor substitution in rice cultivation are shown in Table 3, comparing the average of three recent years with that in the period before mechanization. The data show the differences for the first rice crop, the second rice crop, and a weighted average of the two. In the weighted average the following results are obtained:

(1) In soil preparation, 5.6 machine hours substitute for 12.3 man-days of labor.

(2) In harvesting, 0.1 machine hours substitute for 3.7 man-days.

These are the only two items for which data presently available permit comparison.

Some Past Empirical Studies in Taiwan.

There have been four empirical studies in which the relationship between labor and machinery is discussed. These are summarized here.

I. Young has reported a 1960 investigation of 115 farmers in three localities; I-Lan (north), Changhwai (central), and Tainan (south).[18] A comparative analysis was made before and after adoption of the power tiller. The impact of adoption was two-fold:

(1) A 7 percent reduction in man-days of hired labor.

(2) A reduction in the farm work burden of women.

II. Another study, in 1965, used a sample of 402 farms, 302 machine-operated and 100 dependent mainly on draft cattle.[19] The areas covered 10 counties, one on the east coast and the others on the west coast. On the farms with power tillers:

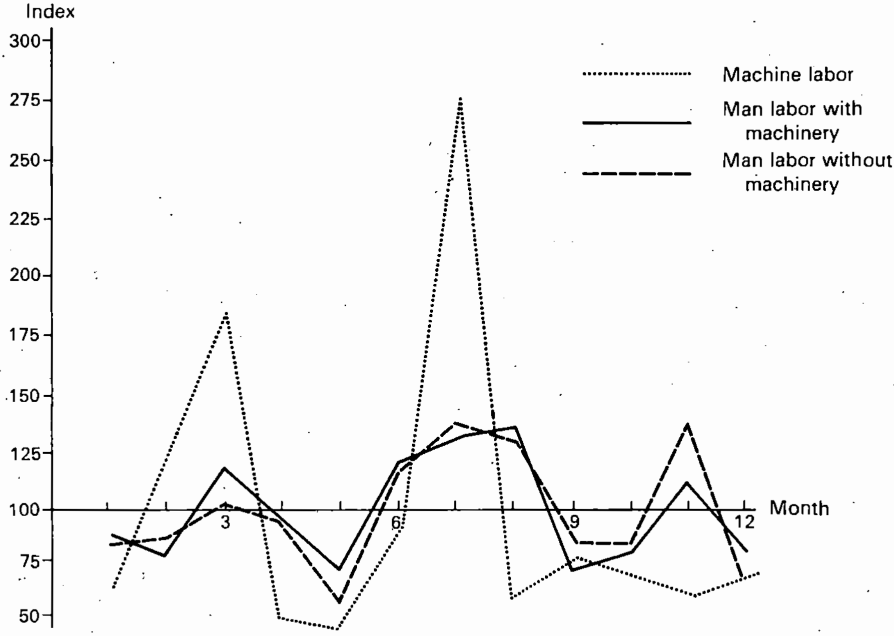
(1) The total labor saved was 3.40 man-days.

(2) The cost saving was NT$3,586.

In comparison, the benefits in Young's study were a total labor saving of 7.51 man-days and a cost saving of NT$3,011.57 (Table 4).

III. A third study used a sample of 28 record-keeping families in three areas, Taipei, Taichung, and Tainan, during 1965, 1966 and 1967.[20] Half of the sample farmers used machinery. The monthly labor utilization varied less on the farms with machines (Figure 2). The use of machines was concentrated in July and

Fig. 2. Seasonal Index of Labor and Machine Utilization in Taiwan.



Source: *Final Report on Experiment in the Comprehensive Use of Farm Machinery of Record-Keeping Families*, Taiwan Prov. Dept. Agr. and For., Dec. 1968, pp. 23–32, and Peng, Tien-song, *The Development of Mechanized Rice Culture in Taiwan*, Tables 39–55.

March because they were used only for land preparation and harvesting in the cultivation of rice. Adoption of machines made possible more timely cultivation, as is shown by the peaks in use of both machines and labor in July. On the farms without machines, the utilization of labor was higher in June and the peak came in August. The use of machines saved 32.24 man-days per year in rice cultivation.

One impact of adoption of machines was to alter the proportions of family labor and hired labor.[21] The ratio changed from about 3-to-1 to about 2-to-1. The total man-days required dropped from 512 to 488, a difference of 24 man-days. However, the farms with machines used 65 less man-days of family labor and 41 more man-days of hired labor. The actual hours of machine use were 65.80, 147.85 and 112.59 hours per year in Taipei, Taichung, and Tainan, respectively, or 109 hours on the average. Hence 109 hours of machine use substituted for 24 man-days. Converting the machine time to 14 8-hour days, the farmers using machines had 10 more man-days for off-farm work or for better management of their farms.

IV. The fourth study, by Lin, used a sample of 10 farms in Changhwai (central Taiwan).[22] The results are as follows:

	Farm with Machines	Farm with Draft Cattle
Labor saved	68.4 man-days/yr.	—
Purchase of power energy	NT$53,400	NT$7,880
Annual expenditure on power	11,200	4,872
Annual receipts from power	38,714	2,220

The farm with machines saved more than two man-months of labor per year and earned more than NT$29,000 income.

Current project at Chung Hsing University.

A "Study of Agricultural Mechanization and Labor Use in Taiwan" has been jointly sponsored by the Research Institute of Agricultural Economics of Chung Hsing University and the Manpower Development Committee, CIECD, Executive Yuan. The major objective is to find out the amount of labor transferred when agricultural operations are mechanized at the present level of adoption on existing mechanized farms. The structure of agriculture in this study is based on conditions in 1969. The technical coefficients on labor-machine substitution, the utilization of saved labor, and the reasons why workers move or do not move out of agriculture are all based on a farm survey made in January 1971 covering the situation in 1970. A sample of 500 farms was selected representing crop systems in six agricultural regions of Taiwan.

In this study, mechanization includes operations on the farm from land preparation and planting to harvesting and drying, but excludes marketing operations such as storage. The contents of the farm survey schedule can be grouped into three parts:

(1) an inventory check on the factors of production on the farm, including the labor situation over the six years 1965–70, as well as land and capital (machines); (2) the utilization of these factors; and (3) the utilization of saved labor and the transfer situation.

Information is obtained on substitution between machine-hours and man-days covering all operations: preparation of land, planting, cultivation, weeding, fertilization, disease and insect control, harvesting, transportation, etc. Utilization of machines and of labor outside the farm are recorded by month before and after purchase of the machine, and monthly variation of farm labor utilization in 1970 is shown.

Salient features of the study are that the substitution between machine and labor is calculated both for different regions and for different crops,[23] and is also determined for all uses of the machine, so that the labor saved is counted both for the owner's farm and for the farms where custom work takes place. It is expected that the substitution in this study will be larger than that in previous studies and will provide a more accurate estimate of labor released for transfer to non-farm sectors.

The following preliminary findings may be mentioned. Labor saved by introducing one power tiller ranges from at least 25 man-days in the Hsinchu area, where the topography is rolling, to over 80 man-days in the Taichung area, where rice cultivation is concentrated. Labor saved by adoption of one harvesting combine ranges from at least 37 man-days in the Hsinchu area to more than 165 man-days in the Tainan area, the great plain on the west coast.

By crops, use of a machine in sugarcane cultivation saves a little over 6 man-days per hectare, but in the second rice crop it saves over 14 man-days per hectare.

On the labor-transfer aspect, the introduction of machines has induced the migration of 3 percent of the original labor force over the past six years, and it would induce the migration of 28 percent of the existing farm labor force if all operations were mechanized.

Concluding Remarks

From the above analysis we can conclude that in Taiwan adoption of machines (mainly the power tiller) both saves labor and reduces costs. It makes operations more efficient, especially through timely cultivation, and more profitable, because of income from custom work as well as from the increase in production already noted. Up to now the annual labor saving has been some 10 to 25 man-days (but the trend is increasing) and the reduction in costs NT$3,000 or more per farm per year.

The labor saved is allocated in three directions:

(1) The reduction in farm work by women has been transferred to management of the household.

(2) The saving of operator's labor on routine tasks has been directed to better management of the farm—there is more time for planning.

(3) The out-migration of young men from farms has provided labor to the non-farm sector.

However, owing to the small amount of labor transfer,[24] mechanization has meant an additional investment in agriculture. When all cultivation operations become mechanized, the transfer of farm labor to the non-farm sector will be greater. Up to now, transplanting and harvesting have not been mechanized, and this is a bottleneck to reducing the excessive seasonal demand for labor in rice cultivation. Therefore, we can be sure that the present operation of farms is far from an optimal combination of resources, by modernization criteria, and nothing can be said about the ultimate level to which the capital-labor ratio will converge.

Regarding the process of mechanization, certain problems concerning the relationship between machine and labor need further study.

The greatest need is for enlargement of smaller units, which generate insufficient income[25] and make inefficient use of agricultural resources in adopting farm mechanization. Small-size farms need to be consolidated into larger family units to allow an increase in the capital-labor ratio and the value productivity of labor.

In the United States, "studies of labor-capital substitution shortly after World War II, when farmers were investing heavily in machinery, reached the cogent conclusion that most operators of cash-grain farms in the Corn Belt had too little land rather than too much power and machinery".[26] This could be a warning to us in advocating farm mechanization only in terms of power tillers of 15 horsepower.

Haque's emphasis that the problem of bringing agricultural mechanization in Pakistan is not basically a problem of purchasing the equipment, but rather that modern agricultural equipment would be useless under the present land system[27] perfectly fits the situation in Taiwan. Farms in Taiwan are rather small and the size is decreasing. The average size of farm dropped from 1.26 hectares in 1952 to barely 1 hectare in 1967, and a majority of the farms are of less than 1 hectare (Table 5). Furthermore, the low resale price of agricultural machinery and its low marginal value productivity outside of agriculture limit the sale of surplus machinery. Therefore, widespread research is needed to indicate the sizes of farms and the amounts of capital necessary to provide satisfactory returns to those who can manage additional resources.

In mechanized farming the work emphasis will be on the mental side rather than on the physical side. Though the mechanization of agriculture can reduce man's physical burdens, it adds more to his mental work load. The man who operates modern farm machinery must make many decisions and perform many functions to properly use the machines. A farmer once remarked that it took an "iron man" to use the "iron cow" in order to obtain the advantage of deep plowing. The present power tiller, or "iron cow", is hardly a product designed with human factors in mind,[28] i.e., emphasis on comfort and convenience in every man-machine relationship based upon anthropometry (body measurements) and related factors. The labor shortage and out-migration of young men will bring more old men and more women into farm work, and this will further complicate this aspect of mechanization. In addition, due to the diversified nature of agriculture, mechanization needs coordination of efforts between agricultural engineers and those in other disciplines. As Skromme stated, "many great farm equipment developments would have been impossible without help from other disciplines... It took 11 years of cooperation between the plant breeder and the agricultural engineer to make a success of tomato harvesting".[29] O'Brien *et al.* have pointed out that "vital to successful mechanical harvesting of pineapple is uniform

Table 5. Distribution of Farms by Area, Taiwan, 1956–66.

Year	No. of Farms	Size of Farms in Chia*					
		Less than 0.49	0.5–0.99	1.00–1.49	1.50–1.99	2.00–2.99	3.00 and over
1956	40,000	30.15	26.71	16.83	9.82	9.33	7.16
1960	807,000	33.50	27.00	15.00	8.50	8.00	8.00
1966	40,000	37.88	28.77	14.98	8.11	6.61	3.65

Sources: *Report on the 1956 Sample Census of Agriculture*, Committee on Sample Census of Agriculture, Taiwan, Aug. 1959, p. 22.

General Report on the 1961 Census of Agriculture, Taiwan, ROC, Committee on Census of Agriculture, Taiwan Provincial Govt., May 1963, p. 22.

Report on the 1966 Census of Agriculture, Taiwan, Republic of China (5% Sample Census), Committee on Census of Agriculture, Taiwan Provincial Government, Oct. 1967, p. 18.

* One chia = 0.96992 hectare.

fruit maturity and spacing... The change to mechanical harvesting involves switching from the customary three year plant cycle to a two year growth cycle".[30] Pineapple is an important crop in Taiwan. The harvesting of pineapple has traditionally been done by hand. However, with economic development, the labor supply is decreasing, and mechanization will certainly solve this problem. The trend in Taiwan is from a rice economy to a commercialized agricultural economy. Farmers will have to learn new enterprises and associate mechanization with those enterprises.

Improvement of the labor market to facilitate mobility among sectors and firms is desirable. Mechanization of agriculture will certainly release quite an amount of labor. However, "evidence indicates that lack of specific information results in doubts and fears that may contribute to immobility".[31] Furthermore, the transfer of farm labor after mechanization and adjustment of the labor force to non-farm work take time.[32]

To deal with such problems, T.W. Schultz suggested making relevant economic information more complete, making grants or loans to help people move, and investing more in human agents.[33] The extension of compulsory education in Taiwan from six to nine years and the emphasis on vocational schools certainly are designed to help qualify labor for specific jobs needed for further economic development. The creation of new jobs in non-farm sectors and the release of labor from agriculture will no doubt bring about better allocation of human resources. From the standpoint of economic efficiency and social welfare, it is desirable to increase the mobility of farm workers through teaching new skills, providing subsidies or loans to migrants, and establishing employment agencies to disseminate job information.

[1] Chen, H.H., "An Economic Analysis of Small Farms in Taiwan," *Essays of Agr. Econ.* (Chinese Rural Econ. Soc.), 2 : 97–118, Dec. 10, 1967 (in Chinese); Lee, T.H., "Economics of Agricultural Modernization in Taiwan," *Essays of Agr. Econ.* (Chinese Rural Econ. Soc.), 5 : 1–4, Dec. 1, 1970 (in Chinese); Mellor, J.W., and R.D. Stevens, "The Average and Marginal Product of Farm Labor in Underdeveloped Economies," *J. Farm Econ.*, 38(3) : 780–91, Aug. 1956.

[2] Hsieh, S.C., and T.H. Lee, *An Analytical Review of Agricultural Development in Taiwan*, JCRR Econ. Digest Ser. No. 12, Taipei, July 1958. See also Georgescu-Roegen, N., "Economic Theory and Agrarian Economics," *in* Eicher, C.K., and L.W. Witt, eds., *Agriculture in Economic Development*, McGraw-Hill Book Co., 1964, pp. 144–69; Mellor, J.W., "The Use and Productivity of Farm Family Labor in Early Stages of Agricultural Development," *J. Farm Econ.*, 45(3) : 517–34, Aug. 1963.

[3] The agricultural adjustment problem in the U.S. more than a decade ago differed from that in Taiwan today. In the U.S. the problem was farm product surplus with excess resources engaged in agriculture, while the problem in Taiwan is to maintain the production of farm products to avoid price increase, or in other words, to modernize the agricultural sector along with economic development. See Heady, E.O., and L.G. Tweeten, *Resource Demand and the Structure of the Agricultural Industry*, Iowa State Univ. Press, 1963, pp. v-vi.

[4] Fu, T.C., "The Application of Farm Machinery in Taiwan," *J. Taiwan Bank*, 11(1) : 96–105, March 1960 (in Chinese); Hsu, Wan-Chun, "The Promotion of Farm Mechanization in Taiwan," *Industry of Free China*, 31(5) : 29–40, May 25, 1969.

[5] In the development of the farm equipment industry in the United States, the tractor came first, in 1912, later the harvesting machine, in 1928. See Skromme, A.B., "The Growth of ASAE and the Farm Equipment Industry 1907–1970," *Agr. Engineering*, 51(4) : 181–84, April 1970, p. 182.

[6] Lai, W.H., "Investigation and Study of Draft Cattle in Taiwan," *J. Taiwan Bank*, 11(1) : 106–30, March 1960 (in Chinese), p. 108.

[7] Problems included high cost of machinery, small scale of farming and fragmentation of land holdings, lack of facilities for servicing machines, and low quality of the machine. See Peng, Tien-song, *A Survey of the Utilization of Power Tillers and Mist-Blowers in Taiwan*, JCRR Plant Industry Div., March 2, 1970 (mimeo.), and Peng, Tien-song, "Present Problems and the Future of Agricultural Mechanization in Taiwan, Republic of China" *Industry of Free China*, 35(4) : 15–24, April 1971.

[8] Lin, T.L., and H.H. Chen, *Rural Labor Mobility in Taiwan*, JCRR Rural Econ. Div., Dec. 1969 (mimeo.), p. 5, Table 2.

[9] Heady and Tweeten (op. cit., p. 229) found that the hired-labor work force in United States agriculture decreased 1·75 percent per year from 1926 to 1959, and predicted a continuing decline.

[10] Chancellor, W.J., "Agricultural Mechanization and World Food Needs," *Agr. Engineering*, 50(8) : 456–60, Aug. 1969, p. 459.

[11] Chinese Mechanization Study Mission to Japan, *Report on Agricultural*

Mechanization in Japan, JCRR Spec. Rept. No. 31, Oct. 1959 (in Chinese), p. 76.
[12] Johnson, D.G., "Labor Mobility and Agricultural Adjustment," *in* E.O. Heady *et.al.*, eds. *Agricultural Adjustment Problems in a Growing Economy,* Iowa State Coll. Press, 1958, p. 170.
[13] Orsagh, T.J., and P.J. Mooney, "A Model for the Dispersion of the Migrant Labor Force and Some Results for the United States, 1880–1920," *Rev. Econ. and Stat.*, 52(3) : 306–12, Aug. 1970; Todaro, M.P., "A Model of Labor Migration and Urban Unemployment in Less Developed Countries," *Am. Econ. Rev.*, 59(1) : 138–48, March 1969.
[14] Johnson, S.S., and E.O. Heady, *Demand for Labor in Agriculture,* Iowa State Univ. Dept. Econ. and Soc., CAEA Rept. 13T, 1962; Schaefer-Kehnert, W., "Farm Mechanization in the Developing Countries," *Economics* (Inst. for Scientific Co-operation, West Germany), 1 : 88–111, 1970; see also Report of Chinese Mechanization Study Mission to Japan (previously cited).
[15] Cromarty, W.A., *Demand for Farm Machinery and Tractors,* Michigan Agr. Exp. Sta. Tech. Bul. 175, 1959; see also Heady and Tweeten, op. cit.
[16] Arrow, K.J., H.B. Chenery, B.S. Minhas, and R.M. Solow, "Capital-Labor Substitution and Economic Efficiency," *Rev. Econ. and Stat.*, 43(3) : 225–50, Aug. 1961; Ruttan, V.W., and T.T. Stout, "Regional Differences in Factor Shares in American Agriculture: 1925–1957" *J. Farm Econ.*, 42 : 52–68, Feb. 1960.
[17] Kao, J.H., "Review of Land-To-The-Tiller Policy Through the Enlargement of Farm Size," *Chinese Econ. Rev.* 7 : 5–8, Sept. 24, 1970 (in Chinese).
[18] Young, J.W., "A Review of the Problems Concerning the Use of Power Tillers by Farm Families in Taiwan," *J. Taiwan Bank*, 14(3) : 39–71, Sept. 1963 (in Chinese).
[19] (Anonymous) *Report on the Investigation of Utilization of Power Tillers in Taiwan*, Taiwan Prov. Dept. Agr. and For., March 1966 (in Chinese).
[20] (Anonymous) *Final Report on Experiment in the Comprehensive Use of Farm Machinery of Record-Keeping Farm Families*, Taiwan Prov. Dept. Agr. and For., Dec. 1968 (in Chinese).
[21] Wang, I.T., *An Investigation Study of Agricultural Labor Mobility in Taiwan*, Natl. Taiwan Univ. Dept. Agr. Econ., Feb. 1970 (in Chinese).
[22] Lin, Chin-Tsao, *Economic Study on Land Consolidation and Agricultural Mechanization*, Chung Hsing Univ. Dept. Agr. Econ., 1971 (in Chinese).
[23] Kudo, Z., *A Study of the Problems of Farm Mechanization in Taiwan*, JCRR Spec. Rept., Sept. 1970 (in Chinese). See p. 4.
[24] Huang, C.L. "Supply Price of Agricultural Labor in Taiwan," *Essays of Agr. Econ.* (Chinese Rural Econ. Soc.) 4 : 11–26, Dec. 1. 1969 (in Chinese).
[25] Chen, H.H., article cited.
[26] Heady, E.O., "Adjusting the Labor Force of Agriculture," and Discussion by C.W. Crickman, in E.O. Heady *et.al.*, eds., *Agricultural Adjustment Problems in a Growing Economy*, Iowa State Coll. Press, 1958, p. 161.
[27] Haque, S.M. Najmal, "The Mechanization of Agriculture in Pakistan," *Agr. Engineering*, 51(3) : 143–45, March 1970, p. 143.

[28] Bellinger, P.L., "Man-Machine Compatibility," *Agri. Engineering*, 50(1) : 17–21, Jan. 1969.

[29] Skromme, op. cit., p. 181.

[30] O'Brien, Michael, W.H. Kahl, and Lee Moffett, "Is Mechanically Harvesting Pineapple Practical?" *Agr. Engineering*, 51(10) : 564–65, p. 564.

[31] Smith, Eldon D., "Nonfarm Employment Information for Rural People," *J. Farm Econ.*, 38(3) : 813-27, Aug. 1956, p. 827.

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DEMAND AND SUPPLY OF AGRICULTURAL LABOR IN RELATION TO MECHANIZATION IN THAILAND

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In Thailand, as in developing countries throughout the world, it is commonly assumed that there is underemployment in the agricultural labor force.[1] There are several indications, however, that there may not be underemployment in Thai agriculture.

Perhaps the most important indication is the level of Thai output relative to non-labor inputs. Calculations suggest that Thais have available to them only 1/45 as much power (horsepower hours) per person as Americans have; yet the Thai laborer produces about four times as much per unit of power used as does the American laborer. Furthermore, the American worker has nearly four times as much land as the Thai, and an incomparably larger amount of new technology to combine with his labor. The implication is that the per capita labor input in Thailand is very high indeed; and this is supported by an International Labor Office study which found that 50 percent of Thailand's population is in the labor force, as compared with only 36 percent of the U.S. population.

Despite the arguments pro and con, little is actually known about the total demand and supply of Thai agricultural labor, whether underemployment really exists, and if so, where, to what extent, and at what times of the year. Only research into this question would help to answer these and important related questions: the effect which decreases in the number of people working in agriculture would have on agricultural output, how fast mechanization in agriculture can be expected to proceed and what its effects on the employment situation will be, the potential supply of labor for non-agricultural production, etc.

Curiosity about this matter led Kasetsart University, in cooperation with the Agricultural Development Council and the ECAFE/FAO Bangkok Office, to support this writer in carrying out a research project, "Labor Utilization among the Households of Rice Cultivators in the Central Plain, Thailand," in the 1961–62 crop year. This case study indicated that on the basis of 312 standard annual working days, rice farmers were employed 130 percent of the standard time during the planting season and 115 percent during the harvesting season. Their labor use for rice production alone exceeded the standard time per four-week period in the peak planting season.[2]

Objectives

The objectives of this paper are to present briefly:

1. Estimates of the aggregate supply of and demand for agricultural labor in Thailand in 1960.

2. The extent of seasonal variation of demand for labor in agriculture compared to the amount of labor available to agriculture, by month, for the country as a whole and by region.

3. Socio-economic aspects of underemployment in Thai agriculture.

4. Economic and social aspects of farm mechanization in Thai agriculture.

Supply of Labor

Labor supply or the stock of labor in Thai agriculture is classified into two categories: number of persons aged 14–60, and number of man-equivalents. Persons aged 14–60 residing in agricultural households (in 1960) are considered as farm workers (farmers are included). Persons 13 years of age and below residing in agricultural households in 1960, who numbered about 8 million, or 30 percent of the total population, are not considered as workers on the ground, based on certain previous research results, that their opportunity cost of labor outside their families is not significant. Persons aged 61 and over in agricultural households in 1960, who numbered about 800,000, or 3 percent of the total population, are not considered as workers for the same reason. The number of man-equivalents is calculated from persons 11–60 years of age.[3] In arriving at net labor supply in agricultural households, (both number of persons and number of man-equivalents), one woman between

21 and 50 years of age (or 0.8 man-equivalent) is excluded for each agricultural household, based on the number of agricultural households in 1960.

On the basis of the above calculation, net agricultural labor supply in 1960 in terms of number of persons aged 14–60 amounted to 7,367,863, or 27.15 percent of the total population; and in terms of man-equivalents it amounted to 6,568,500 or 24.21 percent of the total population.

Work-days available per worker are estimated at 280 a year for men and 268 for women. This averages out to approximately 5.5 and 5.1 days per week, respectively.[4] Workdays available over the year and per month were calculated on this basis.

Demand for Labor

The estimates of labor demand in Thai agriculture are based on two types of information,[5] (1) average labor input (workdays of 8 hours) per rai of crop or per head of livestock in the production of certain crops and livestock, and (2) area cultivated of each crop and numbers of livestock. (One rai is 0.395 acre or 0.16 hectare.) Total demand for labor in crop and livestock production is number of rai cultivated times average labor input per rai plus number of livestock times average labor input per unit of livestock. Labor demand for minding buffaloes and cattle, including work animals, however, is based on the number of animals in the province or region in 1960 and number of agricultural households in the same year. The writer's study, "Labor Utilization among the Households of Rice Cultivators in the Central Plain, Thailand, 1961–62," showed that each rice-growing household spent 120 workdays of its available labor stock for minding buffaloes and cattle. The Census of Agriculture, 1963, reported that 96 percent of agricultural households holding 2 or more rais of farmland grow rice. Total demand for labor for taking care of buffaloes and cattle is estimated as the number of agricultural households in the province or region times 120 workdays.

In order to arrive at the variation and extent of labor demand over the year and the amount of labor used in agriculture by month, official reports on the growing season for 24 major crops were used and persons experienced in the production of various kinds of crops and livestock were consulted. In view of variation in the growing season of crops such as rice, the monthly rainfall pattern in the defined regions was consulted. If the growing seasons of certain crops overlapped within a month, demands for labor for each crop were added together. This indicates peak or slack seasons of demand for labor over the year.

It should be noted here that the labor input per rai of crops and per head of livestock is an average of actual labor used. Certain factors such as travelling time of workers between farm and place of work are not included. Also the range of labor input varies considerably. For instance, workdays per rai in rice production reported by various research workers ranges from 9 to 16.

Furthermore, even if the growing season of crops is known, it is still very difficult to estimate distribution of workdays by month for crop production. Complete information on workday distribution by month and by kind of work in the production of rice, corn, and kenaf is available. For the production of other crops, distribution of the total workdays by month is mainly based on personal experience and consultation with experienced persons and technicians.

After tabulation of collected data, a graph was made and compared with the writer's previous study, mentioned above. The workday distribution by month in crop production was similar. Actually, the average labor input for rice production constitutes 79 percent of the total average labor input for the 24 major crops. If the workdays used for the production of rice, corn, and kenaf, for which the information on workday distribution by month is considered complete, are added together, they amount to 85 percent of the total average labor input for the 24 major crops.

Underemployment in Thai Agriculture

In this paper, underemployment is defined in two ways: (1) a situation in which the withdrawal of labor to other uses will not appreciably diminish the total output of agriculture, and (2) a situation in which the full number of labor hours or workdays available is not being utilized.

The first relevant question is whether underemployment under the first definition exists in Thai agriculture. On the basis of what was found in the case study of rice production, inductive reasoning would lead us to answer no. On the other hand, present analysis seems to suggest that 3 percent of the workdays available in terms of man-equivalents, or 13 percent in terms of farm workers (persons aged 14–60 in agricultural households), could be removed to other uses without any decrease in agricultural output. (If one looks only at the annual totals, one might make the misleading generalization that underemployment of the workers in Thai agriculture amounted to 40 to 46 percent in the year under consideration.)

At this point in the analysis, at least two relevant facts must be considered. First, as already stated, only the actual average labor input for crop and livestock production is used for calculating the working hours or days of the workers. The unavoidable delay of labor use caused by such factors as soil structure, farm layout, travelling to and from a distant farm, work preparation and after-work labor requirements, etc., is not included in the calculated average labor input. Second, although hours available for work are divisible, workers are not. Due to the existence of peaks in seasonal demand for labor in the agricultural sector, the permanent removal of some agricultural workers for other uses in the industrial sector would negatively affect agricultural output, since work hours needed in the peak season will have gone with the workers removed. The 3 or 13 percent of workdays available which appear to go unused may actually be used for producing crops (including second crops) or livestock which were not included in the 24 major crops and 5 kinds of livestock under consideration, or may be used for non-farm jobs.

For the second type of defined underemployment, the analysis seems to suggest an answer of yes. Many developing agricultural economies are characterized by semi-subsistence family farming, traditional value systems, lack of certain old or new factors of production, and absence of product price incentives. In such a situation, this type of underemployment is more likely to prevail than the other one. This type of underemployment requires much application of socio-economic analysis.

If the country is divided for our analysis into ten regions,[6] the relationship between demand for labor in agriculture and the amount of labor available by month in 1960 varied from region to region. The seasonal demand was similar among the regions except in the Near Northeast and the South. In these two regions rice production is relatively less predominant in labor input.

Based upon the peak demand for labor in relation to the workdays available, the man-equivalents in the Near Northeast, the North and the West regions registered the highest underemployment—around 30 percent. On the other hand, in the Central Plain, the East and the South regions the labor use in man-equivalents in the peak period exceeded the standard time by approximately 50, 30 and 12 percent respectively. The rest of the regions utilized their monthly man-equivalent workdays similarly to the average in the country as a whole.

Economic and Social Aspects of Farm Mechanization in Thailand

Two aspects of farm mechanization in Thailand are discussed briefly in this paper. First, does farm mechanization increase productivity and farm income? Second, what will be its effect on employment and other social situations?

Productivity and farm income effect

The effect of farm mechanization on productivity and income depends mainly on kinds and uses of machinery. Certain kinds of machinery such as water pumps help increase intensive labor use and, of course, affect productivity and income of farmers. Also, some kinds of machinery such as farm tractors will expand labor use. For instance, before the introduction of water pumps and similar machinery to Thai agriculture, most farmers could not grow second crops on their land; also only after the advent of farm tractors could farmers expand their area of cultivated land, especially for floating rice, corn, sorghum, cotton and kenaf. This is because typical farm tools and animal power cannot plow the land before the coming of rain, for the land is not soft enough.

As regards tractors, 90 percent of farm tractors in Thailand are owned by custom-service operators, who generally also are farmers and who provide farm services for a fee. Operators are typically small in scale, having 1 to 5 tractors and 1 or 2 implements per tractor—generally a plow and either a harrow, rotary tiller, trailer, or corn sheller.

Tractors are used predominantly for land tilling. Farmers principally use the tractors' considerably higher productivity over draft animals to enable preparation of more land in close coordination with climatic conditions. Tractors are heavily used in the production of corn, sorghum, cotton, and sugar cane. Their use for other upland crops is not as extensive nationally. Tractor use for rice production is heavy in the Central Plains and South, but limited elsewhere.

Greater physical ease in accomplishing work and time freed to earn income from other sources rank high in farmers' minds as reasons to use tractor services—higher than the relative cost/output advantage of tractors over other power sources. This belief of farmers is substantiated in Table 1.

Table 1. Change in Average Income of Farm Households in Thailand, 1953 to 1964.

Source of income	Income		Percentage increase	
	1953	1964	Total	Per year
	(baht)			
Agriculture	3,240	4,008	23.70	2.15
Off-farm work	1,756	2,430	38.38	3.49
TOTAL	4,996	6,438	28.86	2.62

Source: 1953 from Division of Agricultural Economics, Office of the Under-Secretary, Ministry of Agriculture, *Economic Survey of Farm Holdings,* 1953; 1964 from National Statistics Office, *Household Expenditure Survey 1963.*

At present, farm mechanization in Thailand is economical for farmers and produces a profit to custom service operators. Farmer use of equipment services, even to the limited extent now applied, considerably expands farm productivity and lowers both unit and overall farm production costs. This is particularly important in Northeast Thailand paddy farming, where equipment use and farm income are the lowest in the country.[7] Paddy farmers in that region, who live at subsistence income levels, are estimated to be able to obtain at least 692 bahts additional income per year per average 21-rai (3.36 hectare) farm from minimal mechanization. Custom-service operations, nationally, are estimated on the average to generate sufficient cash income to pay out investment in about 4 years plus providing additional benefit from use of equipment on operators' own farms.

Need for accelerated farm mechanization

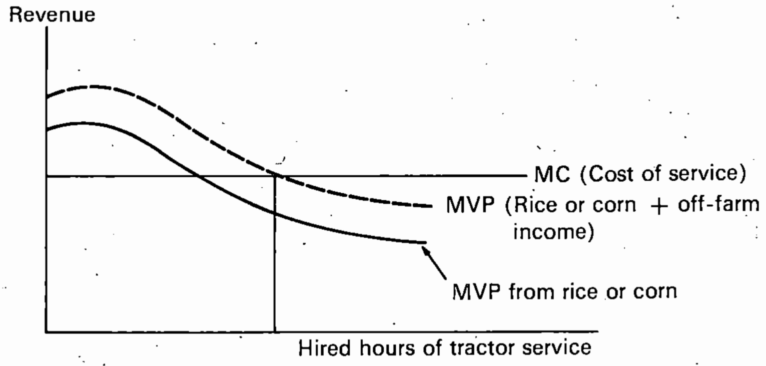
The shortage of farm labor and of draft animals in peak farming seasons indicates the significant need for increased mechanization. The existing national shortage of farm power in peak farming seasons found in the survey[8] is further demonstrated by the inverse relationship in Thailand of crop yield and farm size. That is, the larger the farm the smaller the yield for most crops.

Present farm power shortages and need for mechanization will be aggravated in the near future, particularly in the Northeast, where major irrigation projects are expected to come on stream by 1971. The Pa Mong Study Project Team projects a significant increase in farm power requirements in the Northeast, with up to 50 percent of the power having to be hired in peak seasons to enable effective use of land to be irrigated.[9]

It should be noted here that crop production in Thailand at present prices of inputs and of products cannot profitably be fully mechanized. Corn and sorghum production at Farm Suwan of Kasetsart University, which was fully mechanized, encountered a loss, while corn farmers in the same locality using machinery (tractor) only for land preparation registered a profit.[10]

Employment and other social effects.

As previously discussed, certain kinds and uses of machinery in Thailand should increase employment. In relation to tractor service for land preparation, two kinds of positive employment effects could occur: (1) increase in farm productivity and hence marginal value product; and (2) greater physical ease in accomplishing work and time freed to earn income from off-farm employment. This effect is illustrated in the following diagram:



Concerning other social aspects of farm mechanization, Thai farmers working with typical farm tools and animal power have a back-breaking occupation. During the peak seasons the farmers and working members of their families were employed 130 and 115 percent, respectively, of full time. Their food intake is too low to provide the calories required by persons engaged in hard work, due mainly to lack of time to obtain food and lack of knowledge about good food.

As a result, when farm people reach about 45 years of age, their working hours per year decrease rapidly and they have to hire labor to do their farm work. Furthermore, a great number of them crowd the provincial and nearby hospitals. This means both a personal cost and a social cost.

In the last analysis, one would not be wrong to say that farm and other mechanization introduced to Thai agriculture and society over the last decade has played a very important role in the improvement of life expectancy and health among the Thais.

Summary and Conclusions

In light of this analysis and discussion, it can be said that there is no underemployment of Thai agricultural labor in the sense that labor could be withdrawn for other uses without a decrease in the total output of agriculture. However, there is underemployment in the sense that the full number of labor hours or workdays available is not being utilized.

One relevant implication for policy should be drawn from this paper. In 1960, one farm man-equivalent or one farm worker produced farm products for only about 4 persons in the country. In that year, the equivalent of 1,062 million 8-hour days were used to produce 24 major crops and 61 million head of 5 kinds of livestock. This contributed only about 3.40 baht per hour to Thailand's gross domestic product derived from agriculture at that year's prices.[11]

Productivity of labor per hour of work in Thai agriculture is relatively low. Rapid transfer of labor from agriculture to non-agricultural production could hardly be expected except at the expense of agricultural output upon which the Thai economy depends.

To help Thai farm workers use their labor more productively and to promote their higher income as well as their better living, proper farm mechanization is one of the positive approaches. However, to achieve higher and stabilized farm income, change in farm management, in knowledge and technology, and in institutions has to be developed correspondingly.

[1] See A. Lewis, "Development with Unlimited Supplies of Labor," *The Manchester School*, May 1954; R. Nurkse, *Problems of Capital Formation in Underdeveloped Areas*, Oxford Univ. Press, 1953; Rosenstein-Rodan, "Problems of Industrialization of Eastern and Southeastern Europe," *Economic Journal*, June-Sept. 1943; J.C.H. Fei and G. Ranis, *Development of the Labor Surplus Economy*, Richard D. Irwin, Inc., 1964.

[2] Arb Nakajud, "Thai Agricultural Labor: Demand and Supply," *Proceedings of the Third National Seminar on Population*, National Research Council, Bangkok.

[3] *Ibid.*

[4] See: Yong Sam Cho, *Disguised Unemployment in Underdeveloped Area: With Special Reference to South Korean Agriculture*, Univ. of Calif. Press, 1963, p. 61.

[5] Arb Nakajud, *op. cit.*

[6] Arb Nakajud, *op. cit.*

[7] Kasetsart University and USOM/Thailand, *Thailand Farm Mechanization and Farm Machinery Market, 1969*, p. 3.

[8] *Ibid.*

[9] *Ibid.*

[10] Dept. of Agri. Econ., Kasetsart Univ., Bangkok, *The Agro-Economics of Corn and Sorghum Production*, July, 1971.

[11] This is based only on the value of crops and livestock. Of the crops, the value of vegetables and fruits, which account for about 23% of the total value of agricultural crops included in the GDP estimate in 1960, is excluded. See: Office of the National Economic Development Board, Bangkok, *National Income Statistics of Thailand*, 1964, Tables 1 and 7.

A SOCIO-ECONOMIC ANALYSIS OF FARM MECHANIZATION IN ASIATIC PADDY-FARMING SOCIETIES WITH SPECIAL REFERENCE TO KOREAN AND JAPANESE CASES

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The so-called "Asiatic Paddy-Farming Society" is characterized as a peasant economy with a large number of family members on small-scale farms, using primitive technology and being subject to a monsoon climate.

In this context, introduction of farm machinery in the area has been considered hardly practical for three reasons. The first is a doubt regarding the technical possibility of developing farm machinery satisfactorily adapted to Asian farming conditions.[1] The second is a wide-spread skepticism whether labor-intensive agriculture can be mechanized without a decrease in yield per hectare, which would be against the farmers' interest.[2]

These two are essentially technical problems and have practically been solved in the process of farm machinery development since 1966. Machines have been devised for all operations of rice farming from planting to harvesting, and this has been done without any reduction of production rate.[3]

Thirdly, even if these two difficulties were satisfactorily solved, a strong doubt has been expressed regarding the economic feasibility of introducing machinery in small-scale farming, especially on those farms with land acreages of one hectare or less.[4] To deal with this problem, many Japanese scholars have advocated socialistic solutions which aim to consolidate small farms into large-scale farms such as kolkhoz or co-operative farms,[5] or enlarging average farm size through decreasing the rural population and the number of farm households.[6] The present study, however, found that the effects of the above proposals on Japanese farm mechanization have been negligible. In 1969, cooperative farms accounted for only 1.0 percent of total farm households, and the average farm size increased only by 0.1 ha. during 1955–69, despite a decrease of about 11 million farmers and 6.2 million farm households during the same period.

Among the three restrictions for farm mechanization presented above, the last question is still unanswered. Then, what are the economic factors overlooked by the Japanese scholars of twenty or thirty years ago, that have made possible the achievement of farm mechanization by small-scale farms?

Research Approaches to Farm Mechanization in Japan

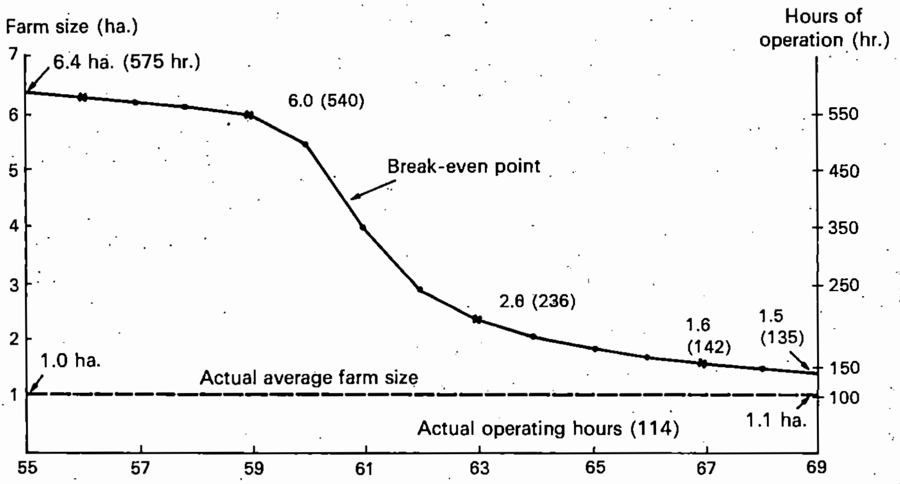
We may group the approaches to factors affecting farm mechanization prevailing in the Japanese academic school into the three categories: (1) break-even point analysis, (2) farm management analysis, and (3) non-economic approaches.

Break-even point analysis

The break-even point is determined where the total cost of operating machinery per unit of land equals the farm operating expenses of conventional farming techniques on the same area.[7] If a farmer has more farm land than that indicated by the thus-calculated break-even point, he can introduce the machine reasonably and use it efficiently on his own farm land. If the opposite is the case, there will be an over-investment problem. To check regarding farm mechanization in this respect, the power tiller was taken for the break-even point analysis, for it is the most important and characteristic machine in the process of Japanese farm mechanization. As of 1969, about 3 million power tillers were being used in Japan, and more than 72 percent of them were owned by small farmers with less than 1.5 ha. of farm land.

Estimates of the break-even points of the 5 HP tiller during the period 1955–68, based on data of paddy-growing farms, are shown in Figure 1.[8] As shown in the figure, the break-even point has moved sharply down from 6.4 ha. (575 operating hours a year) in 1955 to 1.5 ha. (135 operating hours a year) in 1968. The reason for this is that while the price of a power tiller increased only by 40 percent, the average farm wage rate rose by 312 percent during 1955–69. This implies that introduction of the power tiller was stimulated as a means to lessen the burden

Fig. 5. Break-even Points of Power Tiller and Actual Average Farm Size in Japan, 1955–69.



Source: Calculated from *Statistics for Agriculture, Forestry and Fishery,* 1955–1970, Japan.

of the sharp wage increase.

By 1968, the break-even point had fallen almost to the average farm size of 1.1 ha. Before reaching this point, there were substantially large gaps every year between the break-even point and the actual average farm size. These gaps obviously imply an over-investment of capital and the inefficient use of a power tiller on the part of most individual power-tiller owners.

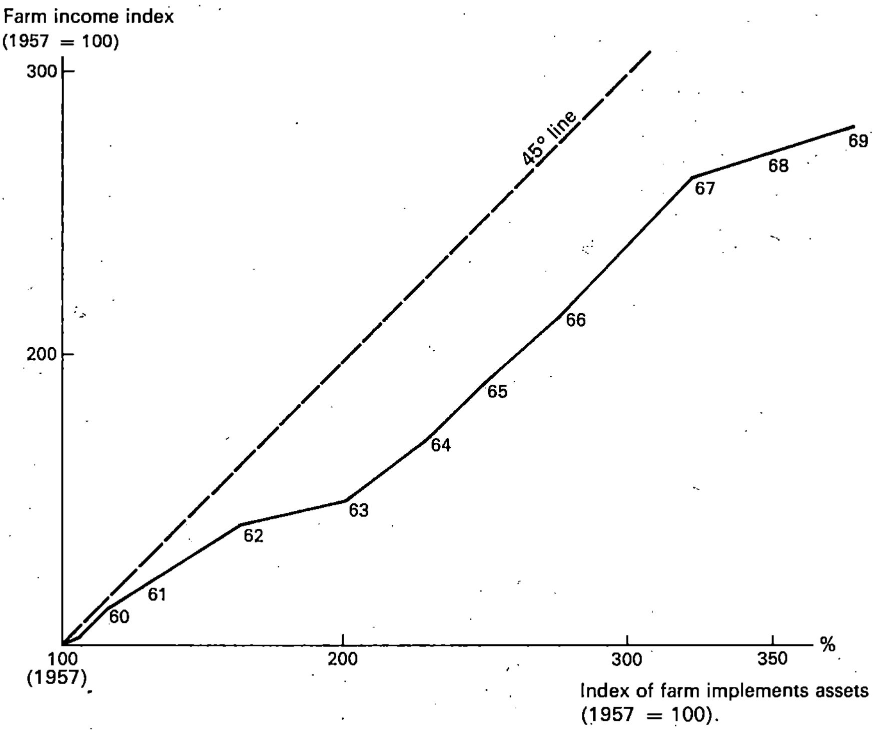
Farm Management Analysis

An alternative approach by Japanese scholars—Teru Takei, for instance—is that the economic efficiency of the power tiller should not be determined simply by the break-even point, but by the over-all impact of mechanization on farm operation as a whole.[9] In other words, feasibility analysis of farm mechanization should not be based on the concept of comparative operation expenses, but on that of induced farm income effect. According to this concept, the comparative disadvantage of machinery introduction viewed from a break-even point analysis may turn out to be a profitable opportunity; the induced income effect on the over-all farm operation may outweigh the capital over-investment.

The above proposition presupposes that farm income should increase faster than the growth of investment in farm implements and machines, so that earnings from agriculture enable a farmer to purchase the machinery. However, factual observation of the process of Japanese farm mechanization contradicts Takei's theory, in that the growth rate of farm implement assets exceeds that of farm income.

As seen in Figure 2, during the period 1957–69 the farm implement index increased to 355 percent and the farm income index to 274 percent, a difference of 81 percentage points, in

Fig. 2. Index of Farm Income and Farm Implement Assets per Farm Household, Japan, 1957–69.



Source: Calculated from *Statistical Yearbook of Ministry of Agriculture and Forestry*, 35th–45th Japan.

nominal prices. The average annual growth rate of farm implement assets is 12.4 percent, and that of farm income only 9.7 percent. In short, farm income did not grow as fast as farm implement assets.

In this context, we can not satisfactorily explain the high machinery investment by the use either of farm management analysis or of break-even point analysis. Again, what has enabled the Japanese farmer to invest in farm implements which grew faster than their farm income?[10]

Non-economic approaches

With regard to the capital over-investment which can not be explained by the above economic approaches, several Japanese scholars had presented non-economic theories[11] such as:

(1) Income Effect Theory
(2) Demonstration Effect Theory
(3) Disintegration of Patriarchal Family Theory
(4) Increased Leisure Valuation Theory
(5) Farmers' Physical Mutation Theory
(6) Combined Factors Theory[12]

Do farmers purchase power cultivators or other agricultural machinery as durable consumer goods, like T.V. sets or refrigerators? Did the demonstration effects, along with the increase of leisure time, motivate the farm mechanization in Japan? All the above questions are chiefly concerned with the non-economic aspects of Japanese farm mechanization. While these non-economic and psychological factors are important, it is essential in the first place to discover the major economic factors covering the over-invested farm mechanization in Japan.

Major Factors Affecting Farm Mechanization

In order to find out the factors associated closely with the introduction of power tillers during the period 1955–69, multiple regression analysis was attempted using various explanatory variables. Among them, the following model was considered as the best fit:[13]

$$Y = -276.0 + \underset{(969.0)}{1{,}658.8X_1^*} + \underset{(0.86)}{1.96X_2^*} - \underset{(0.44)}{0.07X_3} \qquad (R^2 = 0.97)$$

where: Y = number of power tillers owned by Japanese farmers
X_1 = farm household income surplus/price of power tiller
X_2 = farm wage rate per day (man)
X_3 = number of draft animals
* = significant at the 1% confidence level

A test of significance of the regression coefficients indicates that the farmers' ability to buy power tillers (X_1) and the farm wage rate (X_2) were statistically significant in explaining the number of power cultivators owned by farmers, while the number of draft animals (X_3) was negatively related but not statistically significant. These variables in the equation accounted for about 97 percent of the variation in the dependent variable (Y).

From the viewpoint of size of coefficient, X_1 is the most effective factor in explaining the number of power tillers. During the test period, the income surplus tripled but the price of tillers increased only by 40 percent. The coefficient of X_2 reflects that as the farm wage rate increases, farmers tend to substitute power machines for human labor.

The significance of the third variable, X_3, is very weak, but the minus sign of its coefficient implies that draft animals in farming have been replaced by power tillers. It is thus safe to conclude from the above regression analysis that farm household income surplus, price of tiller, rural wage rate and the number of draft animals affected farm mechanization, and that the income surplus may be a decisive factor, because a farmer's investment in durable capital assets requires a large amount of cash at one time, and the surplus is the main source of capital accumulation. The next question is where the farm income surplus comes from.

Since the farmers' income surplus originates from both agricultural and non-agricultural income sources, it is necessary to determine the degree of association of each of these two types of income with farm implement assets as follows:

$$Y = a + bZ \qquad \text{.......................(1)}$$

$$Z = cX_1^{\alpha}X_2^{\beta} \qquad \text{.....................(2)}$$

substituting Z from (2) into (1),

$$Y = a + bc\, X_1^{\alpha}X_2^{\beta} \qquad \text{...............(3)}$$

where: Y = value of farm implements and machinery (yen),
Z = farm household income surplus (yen),
X_1 = farm income (yen),
X_2 = non-farm income (yen).

In the above equation, the Cobb-Douglas exponents α and β, can be said to represent contribution rates of farm and non-farm income, respectively, to the value of farm implement assets. Estimates of the exponents, using data for 1955–68, are shown in Table 1.

Table 1. Relative Contributions of Farm and Non-farm Incomes to Farm Capital Provisions by Size of Farm, Japan, 1955–68.

Size of farm (ha.)	Farm income (α)	Non-farm income (β)	R^2
0.1–0.3	–0.164	1.547	0.80
0.3–0.5	–0.219*	1.276*	0.94
0.5–1.0	0.350	0.748*	0.98
1.0–1.5	0.374*	0.510*	0.99
1.5–2.0	0.757*	–0.045	0.99
2.0 or more	1.329*	0.032*	0.96
Y = 30.57 + 1.47Z*	(R = 0.97	t = 13.37)	

Source: See Sung-Ho Kim, *op. cit.*, Appendix Table 5.
* Significant at the 1% confidence level.

The figures in the above table indicate that the contribution rate of farm income to farm implement assets (including machinery) is higher than that of non-farm income for farms with 1.5 ha. or more. On the other hand, the opposite is true for farms of less than 1.5 ha., implying that the small-size farmers depend heavily on non-farm income to finance their farm mechanization.

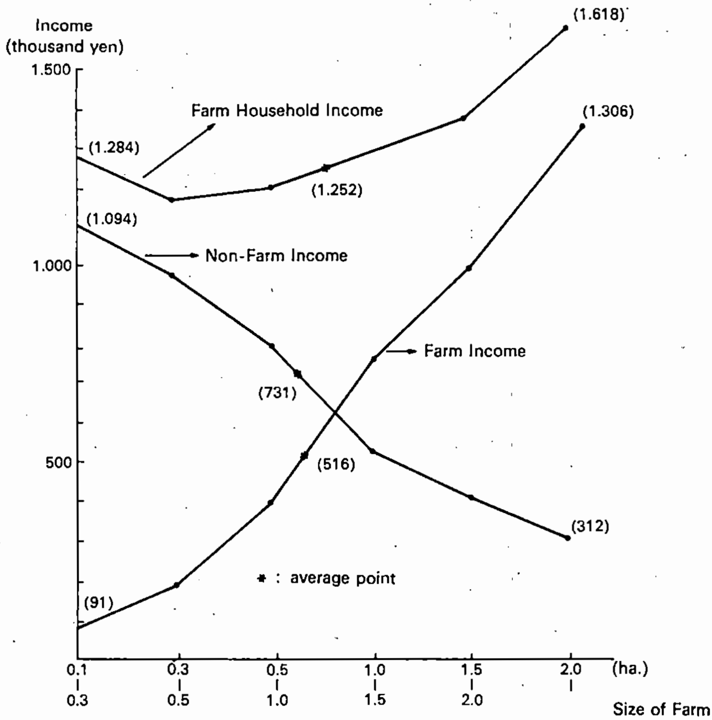
These findings shed light on the earlier findings of the capital over-investment, explaining why and how farm mechanization in Japan has been possible despite the fact that many small farms could not afford to buy a power cultivator when financed by farm income alone. In short, non-agricultural income has played a decisive role in stimulating farm mechanization by providing a reward to the apparent over-investment of capital in farm machinery by Japanese farms. In other words, Japanese farmers have been strongly motivated to adopt the farm machinery in order to increase their non-farm income.

Contradictory as it may sound, the above statement presents a distinctive characteristic of Asiatic paddy-farming society. In reality, non-farm employment in Japan brings farmers twice as large earnings per capita as working on the farm. Therefore, young persons in rural areas take jobs whenever they can in the non-agricultural sector, and this creates a great labor shortage for operation of their own farms. But they don't want to abandon farming because of instability of non-farm employment, uncertain social security, inherent attachment to their farm land, etc. Under these circumstances, a probable solution is to minimize their labor inputs used in agriculture and divert the maximum amount of labor to non-farm employment opportunities. To do so, introduction of farm machinery is needed to make up for the outflow of farm labor, and the resulting capital over-investment is compensated by their high non-agricultural income.

Many scholars in Korea and Japan used to regard the non-farm income as a supplemental revenue mainly for family livelihood, and thus considered the magnitude of non-farm income as a parameter of farmers' poverty.[14] However, high non-farm income not only supplements living expenditure but also constitutes a major part of farm household income, and thereby compensates for the over-investment involved in the introduction of farm machinery. Figure 3 indicates the relationship between agricultural and non-agricultural incomes of Japanese farmers by size of farm.

The high farm household income of small-size farms is mostly due to higher non-farm income. Presently this type of part-time farmer comprises 84 percent of all farm households. Referring to the fact that this percentage has gradually increased from the earlier stage of Japanese capitalization, part-time farm operation may be an essential phenomenon with respect to rural migration

Fig. 3. Farm Household Income Structure in Japan, 1969.



Source: *Statistics for Agriculture, Forestry and Fishery,* 1971, Japan.

in Japan.[15] Under this circumstance, non-farm income plays an important role in increasing farm household income and in agricultural modernization.[16]

Comparison of Mechanization Process: Japan and Korea

Up to this point we have found no reason to suppose that the characteristics we have observed in Japanese farm mechanization are unique to Japan. We might expect to find them in other Asian paddy-farming societies where rapid economic development is in process. But before proposing this controversial generalization, we must make a comparative study of the farm mechanization process in Asian countries.

Comparison of the Korean case with the Japanese case seems to indicate almost the same trend of farm mechanization. The present low level of farm machinery supply in Korea, where approximately 10,000 power tillers are operating as of 1969, makes it extremely hard to analyse the process of Korean farm mechanization using the same method applied to the Japanese case. However, there are some data indicating similarity.

The rapid economic growth of Korea in the 1960s has greatly affected the agricultural sector in such a direction as to stimulate farm mechanization. The number of persons employed in the agricultural sector has decreased since 1965. Also, farm population and the number of farm households have decreased since 1968.

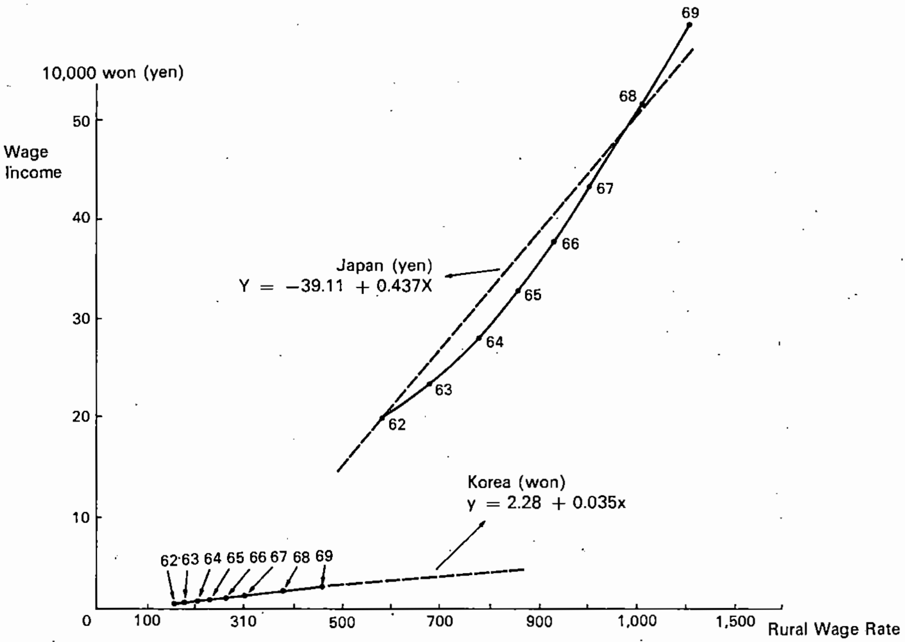
In the present situation of Korean agriculture, a small decrease in labor supply due to the outflow of rural labor causes a great change in the farm wage rate and agricultural productivity, because farm technology still follows conventional labor-intensive farming methods. The farm wage rate in Korea actually has risen faster than in Japan during the 1960s.[17] Strong pressure has developed for adopting farm machinery in order to lessen the burden of the increase in farm labor expenses in Korea. To improve the situation, the Korean government has initiated a program for agricultural machinery supply in the Third Five Year Economic Development Plan that begins in 1972.

Furthermore, Korea is facing almost the same situation as in the initial stage of farm mechanization in Japan, in that the break-even point for the use of power tillers is a little higher than 5.0 ha.,[18] so that mechanization is likely to involve a similar problem of capital over-investment.

Under these circumstances, it is imperative that non-farm income should increase in order to cover the deficit of farm mechanization. Such a process is a necessary pre-condition for farm mechanization in Asian paddy-farming society, where small-scale farming with low levels of farm income is the general rule.

Is the non-farm income of the average Korean farmer at present sufficient to finance the expenditure needed for the introduction of farm machinery? Since more than 80 percent of non-farm income, on the average, comes from farm wage income, which is associated closely with the rural wage rate, a rapid rise in wage rate would appear superficially to provide the increase in non-farm income.

Fig. 4. Relationship of Farm Wage Income and Rural Wage Rate, Korea and Japan, (1962–69).



Source: *Statistical Yearbooks of Ministry of Agriculture and Forestry,* 1963–1970, Korea and Japan.

But in Korea, the wage income does not increase very much with increase in the wage rate. Let us compare the Korean situation with that in Japan. As clearly seen from Figure 4, the association appears to be very strong in the case of Japanese farmers, but relatively poor for Korean farmers. The regression coefficients are positive in both equations, implying that as the rural wage rate rises, farm wage income in both countries increases, but the rates are much different. For the same relative increase in the farm wage level, the increase in farm wage income of the average Korean farmer is about one-twelfth that of a Japanese farmer.

Why is there this difference between the two countries? The explanation is that farm wage income depends not only upon the wage rate but also upon non-farm job opportunity. In the Japanese case, these two factors, wage rate and job opportunity, have risen together, but in Korea the wage rate has risen, because of the decrease in rural labor force, but job opportunities have not expanded.

In Japan, the over-all non-farm job opportunities have been made available to farmers chiefly through the expansion of the external economy and the decentralization of firms and factories in rural areas. With good road development, rapid transportation system, and industrialization in rural areas, farmers have had easy access to part-time jobs nearby their homes or are able to commute daily to and from distant city working places, without having actually to migrate.[19] Under this situation, an increase in rural wage rate was immediately reflected as part of non-farm income in Japan.

In such a situation, the rise in rural wage rate creates not only the necessity for farm machinery on the part of farm operators in order to offset the increase in operating costs due to rising wages, but also an effective demand for farm machinery, which can largely be financed out of non-farm earnings. The farm mechanization process described above in connection with the non-farm employment thesis is what Japanese agriculture has experienced since 1955.

In contrast, Korean agriculture seems to be caught in a vicious circle in regard to farm mechanization. Due to the centralization of industries in a few big cities and with little development of the external economy in rural areas, even when the rural wage rate rises substantially the impact on increased non-farm income appears to be negligible. Accordingly, the rise in the rural wage level has created only a need for farm machinery, which has not been followed by growth of effective demand for purchasing of farm machinery. In other words, with the increasing farm wage rate in Korea, the gap between absolute and effective demand for farm machinery is widening year by year.

The present differences in socio-economic conditions for farm mechanization between Korea and Japan are due to differences in the pattern of modernization, a problem outside the main subject of this paper.

Future Path of Farm Mechanization

Finally, however, let us attempt to evaluate Japanese farm mechanization using small-scale machines—power tillers, binders, planters, etc.—which are quite different from Western, large-scale machinery.

Small-machine mechanization has several weak points. First, it cannot provide a consistently integrated work system like that in Western farm mechanization, where the tractor provides multipurpose services. In Japan, each different machine, such as power tiller, binder, transplanter, etc., requires a separate power source, so that the total cost of machinery is higher than that with the tractor used in Western agriculture.

As shown in Table 2, although the average power of machinery per farmer in Japan is the lowest among the countries listed, the power per hectare is the highest. This means that the Japanese style of mechanization requires relatively more machine power, and hence higher cost, than in the other countries.

Another weak point is that the part-time farm shows a lower land productivity than that of full-time farms.

Thus Japanese small-machine mechanization, mainly designed for small or part-time farms, is found to be inefficient in utilizing agricultural resources. This may be a transitory phenomenon that has resulted from the pattern of part-time farming. If the agricultural population and number of farm households continue to decrease in the long run, the small-machine mechanization will change to large machines.

Table 2. Farm Mechanization in Selected Countries, 1970.

Countries	Average tractor horsepower per farm	Average tractor horsepower per hectare
U.S.	79.1	0.7
United Kingdom	41.2	0.8
France	18.7	1.3
Germany	17.2	2.1
Italy	4.5	1.0
Japan	3.6	2.8

Source: *Farm Machinery Almanac (Sin No Rin Sya)*, Japan, 1971.

The modern professional farmers who want to specialize in farming eventually will adopt the integrated system centered on the use of medium or large-scale machinery. The recent rapid adoption of large tractors by many Japanese farmers is regarded as heralding this new trend. In this context, the present pattern of Japanese farm mechanization is likely to pose problems of transition to the post-small-machine stage of mechanization.

Korea is, instead, in the pre-mechanization stage of small machinery. Mechanization should be preceded by a balanced growth between the agricultural and non-agricultural sectors, in order to provide many non-farm job opportunities. This will be done by expansion of the rural external economy through the decentralization of firms and factories. Thus, for farm mechanization in Korea, the *inter-industry* problem is no less important than the problem *within agriculture*.

However, the introduction of small machinery is not the only path to farm mechanization. Large-scale machinery may be distributed as a strategic means in order to skip the small-machinery stage. But this can be justified only where a simple cropping system is carried out over a wide area, or where farm machinery systems such as cooperative use can be introduced.

Finally, Korea and many other countries in the East-Asian Region except Japan have had such a short practical and theoretical experience with respect to the engineering, technology, and work system of farm machines that their farm mechanization proceeds by trial and error, and progresses poorly.

Thus, the task of farm mechanization in Asiatic paddy-farming societies calls for a comprehensive problem-solving effort, not only *within agriculture* and *between industries* but also *between countries* for exchange of information.

[1] Otsuki, Masao, *National Livelihood and Agriculture* (*Kucka Seikas do Nogyo*), Tokyo, 1939, p. 142.

[2] Yokoi, Sikei, *Agricultural Economics* (*Nogyo Keizaikaku*), Tokyo, 1910, cited by Teru Takai, *An Economic Study of Farm Mechanization in Japanese Agriculture* (*Nihon Nogyo ni okeru Kikaika Kadai do Keiseideki Kosatsu*), Tokyo, 1962, p. 2.

[3] Kim, Sung-Ho, *Prospects of Farm Mechanization in Korea* (*Nongup Kikehwa changi chun Mang*), Seoul, 1970, p. 42.

[4] Ouchi, Tsutomi, *Agricultural Problems* (*Nogyo Mondai*), Tokyo 1951, p. 72.

[5] Kondo, Yas, *What are the Fundamental Agricultural Problems?* (*Naniga Nogyo Kihon Mondai Ka*), Tokyo, 1961, p. 47.

[6] Research Association for Basic Problems of Agriculture, Forestry, and Fishery, *Essential Problems and Basic Policies of Agriculture* (*Nogyo no Kihonmondai do Kihondaisaku*), Tokyo, 1960, p. 58.

[7] Kamidani, Keiji *Analysis of Farm Mechanization in Japan* (*Nihon Nogyo Kikaika do Bun Seki*), Tokyo, 1960, p. 361.

[8] Estimation procedure of the break-even point is as follows:

$$\frac{FC}{B}+VC = OC \quad \ldots\ldots\ldots\ldots(1)$$

$$B = \frac{FC}{OC-VC} \quad \ldots\ldots\ldots\ldots(2)$$

where, B: break-even point
FC: fixed cost of machine per year
VC: variable cost per tanbo
OC: operating cost by conventional methods per tanbo

For detailed information, see: Sung-Ho Kim, *A Socio-Economic Analysis of Farm Mechanization and Farm Machinery Industries in Korea* (*Nongup Kikeha Eui Sahwe Kyunggejuk chekun kwa Nongki Sanup Uksung Chag*), Seoul, 1971, appendix tables 1 and 2.

[9] Takei, Teru, *An Economic Study of Farm Mechanization in Japanese Agriculture* (*Nihon Nogyo ni okeru Kikaika Kadai do Keisaideki Kosatu*), Tokyo, 1962, p. 34.

[10] According to Tsuchiya, "The funds for the purchase of power tiller were from individual resources. Very little capital is secured from the Mechanization Fund (a governmental low-interest fund), or other public sources." Keizo Tsuchiya, *The Role and Significance of Mechanization in Japanese Agriculture*, Kyushu, 1970, p. 15.

[11] Kayo, Nobufumi, *Problems of Mechanization in the Japanese Agriculture* (*Nihon Nogyo Kikaika do Kadai*), Tokyo, 1962, pp. 20–28.

[12] Tsuchiya, Keizo, *op. cit.*, passim.

[13] Kim, Sung-Ho, *op. cit.*, appendix table 4.

[14] Chai, Gion-sik, *The Logic and Basic Condition of Agricultural Modernization* (*Nong-up Kium Da Hwa Eui Nonri Hwa Kibongio-kon*), Seoul, 1966, p. 20, and Tsutomu Ouchi, *op. cit.*, p. 64.

[15] Kim, Sung-Ho, *op. cit.*, appendix table 8.

[16] Kiyomitsu stresses that the reduction of number of farm households in the 1960s is chiefly attributed to the strong tendency of small-size farmers to seek non-farm work opportunity. Yosihiro Kiyomitsu, *The Change in Size of Small-scale Farms under Economic Growth* (*Keyzaisei Goka ni okeru sono no Kiymobetze Hendo*), cited by Keiji Kamidani, *Technical Innovation and Japanese Agriculture* (*Kijutso Kakusin do Nihon Nogyo*), Tokyo, 1969, p. 166.

[17] Kim, Sung-Ho, *op. cit.*, appendix table 9.

[18] Kim, Sung-Ho, *op. cit.*, appendix table 13.

[19] Kasiwa, Hirodaka, *Proper Recognition of Agricultural Problems* (*Nogyo Mondai no Adarasi Ninsiki*), Kyoto, 1966, p. 67.

GROUP ACTIVITIES IN THE MECHANIZATION OF RICE FARMING

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Types of Group Activities in Rice Farming

There are many types of group activities in rice farming, and I want first to describe some types that have been particularly popular in Japan.

Labor exchange between farmers

This type has been very popular for a long time. Japanese farmers usually call this type "Yui", which means "combination" or "binding". A farmer receives labor from other farmers at his busy time and returns the same amount of labor when he is asked to pay back. Of course there is no cash payment between these two farmers. Usually each farmer exchanges his labor with several other farmers.

Group operation of farming practices

Some practices of rice farming (transplanting, disease and insect control, harvesting etc.) are very often done cooperatively. Sometimes only one practice is done cooperatively, sometimes two or three. At present, group operation of transplanting and of disease and insect control are most popular. The size of group varies from several households to as many as 30, almost the same as the size of a village community. The optimum size of group operation differs for each practice.

Group utilization of farm machinery and facilities

Capital investment in farming has been increasing remarkably, especially fixed capital. How to use fixed capital at its optimum level is important if the farmer is to make his farm management stable and profitable.

Because for this purpose many farmers have too little acreage, group utilization of large machinery has been developing. We can divide group utilization into three types:

1. A machine is owned by one person and others use it by paying rent.
2. Each machine is owned by all members of the group using it.
3. The machines are owned by the farmers' association or town government and members of the group borrow these machines and use them as a group.

Group farming (joint farming)

Each farmer does his own farming, but there is group agreement as to varieties, timing and methods of cultivation. This is the most popular type of group activity in Japan, but different groups have widely different ranges of group activities. In the more progressive groups, cooperative performance of farm practices, group utilization of machinery, and agreement on cultivation are closely combined with each other. But the base of group farming is agreement on cultivation by members. Usually the group includes almost the whole village community.

Cooperative management

Under cooperative management all practices are performed cooperatively, not only production practices but also selling and profit sharing. We can divide cooperative management into two categories:

1. Cooperative management of one enterprise.
2. Cooperative management of all enterprises.

What Is Group Farming?

As I stated above, group farming (joint operation of rice farming) is becoming the most popular type of group activity in Japanese farming. It involves serious but interesting problems. In this paper, it is discussed primarily with reference to the mechanization of Japanese rice farming.

It is difficult to define group farming because its ways and means are so multifarious.

Perhaps the largest change in Japan's agriculture in recent years is the outflow of agricultural labor brought about by growth of the non-agricultural sectors of the economy. Farmers have been induced to take countermeasures such as the introduction of large machinery for joint use to replace individually owned small machinery and the adoption of joint water management.

To assure a high rice yield, the most important operations are timely transplanting and irrigation. But to ensure a high unit yield by cooperative adjustment of the depth of irrigation water and cooperative control of disease and insects, the rice growth conditions on all participating farms must be uniform. To assure uniformity all participating farmers have to adopt the same variety and transplant at the same time. Otherwise the adjustment of irrigation water can not be carried out cooperatively because water depth must differ by growth stage and condition. The same is true for disease and insect control.

So the simplest form of group farming operation is the adoption of the same variety, simultaneous transplanting and fertilizer application, and the conclusion of an agreement among the participating farmers for cooperative water management and cooperative disease and insect control.

Usually all operations under the agreement are carried out individually on each farm except for water and insect control. Of course, some operations do not fall under the agreement. Initially, for instance, most harvesting operations are on an individual basis.

Group farming depends on the agreement of participating farmers; its basic foundation is the individual. It is a kind of group activity based solely on agreement, not on contract. Group farming is sometimes called joint farming or translated as group cultivation. However, agreement by members is the basic foundation.

When group farming develops to an advanced stage, it becomes desirable to carry out all plowing and harrowing at one time in preparation for simultaneous transplanting. Then a large tractor is used jointly by the members, with one member who can operate it commissioned to do all the work. To ensure the maximum results with such large machinery, field plots must be consolidated to a certain size and in accordance therewith irrigation and drainage ditches must undergo improvement.

At still more advanced stages, the scope of operations under simple agreement gradually decreases and the scope of cooperative

Table 1. Scope of Group Farming in Japan: Number of Groups and of Participating Households, and Area under Joint Operation, 1966–67; Area Ratio, 1962–67.

	1966	1967
Number of groups	3,317	6,455
Number of households	96,637	201,676
Area in hectares	68,301	145,540

	1962	1963	1964	1965	1966	1967
Ratio of area (includes only operations of 10 hectares or more)	0.3	0.5	0.9	1.3	2.4	4.7

work increases. For instance, transplanting is done not individually but cooperatively. The same is true of harvesting. However, when almost all farming operations are done cooperatively, group farming has turned into cooperative cultivation.

At present, most group farming operations are in the initial stage, and their number is constantly increasing (see Table 1). On the other hand, cooperative rice cultivation is also increasing. However, to avoid any misunderstanding, we emphasize that one must not assume that group farming inevitably develops into cooperative management, although of course this occurs in some cases.

In general, there is a distinct difference in the way farmers look at group farming and cooperative management.

There is some opinion that group farming will soon dissolve—that it is an initial step toward large-scale individual management. Group farming has emerged naturally as a countermeasure of farmers against external pressures, so it has much mobility. Accordingly, it is not incorrect to speak of group farming as temporary.

Yet it is wrong to view group farming as necessarily leading either into cooperative management or toward the birth of large-scale individual management. The mobility of group farming can be interpreted to mean that Japanese farmers are capable of meeting ever-changing situations. Instead of hastening to reach any conclusion, it is necessary to fully ascertain the characteristics and existing conditions of group farming operations. Although group farming seems simple at a glance, it has complex features as well as progressive phases.

Types of Group Utilization of Machinery

Group utilization of machinery and facilities was mentioned briefly in an earlier section. The different types of arrangements are discussed in more detail here.

1. Some groups consist of several farmers who can operate large machines, but the machines are owned by one person and the others use them by paying rent.
2. Some groups consist of several farmers who can operate large machines and the machines are owned by all members of the group. Planned utilization among members is necessary.
3. Sometimes one farmer owns and operates the machinery and the others do not own and cannot operate it. In such case, the owner of the machinery cultivates the others' fields by contract.
4. Sometimes the owner of the machinery is not an individual but a farmers' union or association. Usually one village or one hamlet has one or two farmers' production unions. The union hires machine operators and contracts with the members of the union according to their proposals.
5. A village farmers' union or association may own machinery and facilities, hire operators, and contract with other groups according to their proposals. There are two cases of this type:
a. Contract or commitment with group-operation groups
b. Contract or commitment with joint-farming groups.
6. Until last year, Agricultural Cooperative Associations were prohibited from engaging in cultivation. But now an Agricultural Cooperative Association can do this as its business. So an association may own a number of large machines, hire operators, and make contracts or commitments with individual farmers, group operations, and joint farming groups.

Table 2. Effects of Joint Operation.

a. Effects reported by farmers

Change	Proportion of farmers reporting	
	much	some
	percent	
Increase in yield	35.1	43.7
Stabilization of production	47.9	38.6

b. Effects on productivity

Item	Unit	Before joint operation	1966
Yield	kg. per 10 are	441	501
Labor input	hours per 10 are	161	130

Source: Ministry of Agriculture and Forestry Investigation of Group Farming, 1967.

Evaluation of Group Farming Operation and Mechanization

Productivity and rice farming technique

From the standpoint of productivity, the 1967 investigation of group farming by the Ministry of Agriculture and Forestry revealed that 35.1% of participating groups achieved a "good" yield increase and an additional 43.7% reported some yield increase, which means that nearly 80% had an increase in yield. As to the question whether group farming contributes to the stabilization of rice cultivation, 47.9% reported that stabilization had greatly increased and 38.6% reported some stabilization, which is a high ratio of 86% in favor of group farming.

The yield increase and stabilization effect differ to some extent by regions. For instance, the regions which reported large yield increases were Kyushu, Chugoku, and Shikoku, followed by the Tokai and Kinki regions. Small yield increase was noted in the Tohoku, Kanto and Hokuriku regions. Practically the same trends are seen in stabilization. From this standpoint, the stabilization effect and yield increase from group farming operation are, if anything, more pronounced in regions other than main rice producing regions. So we can say rice productivity has leveled up, especially in the less productive regions.

From the standpoint of labor productivity, 99% of the total number of group-operation groups reported labor saving. For example, the labor requirement per 10 are was about 20% lower.

Now, the question is what kind of mechanism is a connecting link between land productivity improvement and labor saving? As stated above, a thorough and exhaustive management is carried out in group farming operations, incorporating new cultivation technology such as the selection of superior varieties, fertilizer application and adjustment of water depth at different growth stages—which ultimately bring about the yield increase. And these intensive and exhaustive operations are carried out cooperatively. For instance, the average number of disease and insect control treatments under individual management is ordinarily 6, but under group farming it is about 10, yet with less labor requirement because it is done jointly. And in the joint use of a large tractor for land preparation much more labor is saved.

The decrease in labor requirement in group farming is not achieved from group farming alone. Rather, there is another major reason. The labor situation of the part-time farmer dependent on income from an outside job is poor because he has lost his main labor force. But the remarkable feature of group farming is that management by the relatively large-scale farmers makes up for this deterioration of labor force. Wives of part-time farmers become able to do complicated work comparatively easily by being taught the method. Improvement of labor quality in joint operation is one merit which should be pointed out. Accordingly, elevating of low-productivity strata has contributed in large measure to the improvement of land and labor productivities in group farming.

Agricultural structure problems

Today in Japan there is a strong tendency to examine and evaluate all policies and changes in agriculture from the viewpoint of agricultural structure problems. Two salient goals of agricultural structure improvement are (a) decrease in agricultural population and number of farm households and (b) fostering of viable farm management by expansion of management scale. And the problems now being concretely discussed in this connection are: How is the differentiation of farmers' strata progressing? What measures are being taken to promote it? What are the best ways to promote the movement out of farming?

Various measures are being carried out positively, such as expansion of the scale of farm management, alleviating the regulation of agricultural land transactions, and amendment of the Agricultural Land Law (proposed in a bill presented at the Diet session last year). Credit measures have been provided for the improvement and expansion of cultivated land. In short, a competitive relation is to be introduced among farmers to ensure that they can withstand the impact of competition and thereby place Japanese agriculture on a sounder and stronger footing.

Now, from the viewpoint of the two goals of structural improvement cited above, how should group farming be evaluated? By some people, group farming is currently being viewed in an unfavorable light. Because it is carried out in most cases by the village or hamlet as a unit, comprising all farmers as members whether they are comparatively large-scale farmers or small-scale part-time farmers, it is evaluated by some people as an inhibition to the progress of farmer-strata differentiation.

But will group farming operations really inhibit the mobility of farmers in deciding their future? It is true that at one time farmers felt the necessity to take concerted action against the instability of present agriculture by joining group farming operations. But differentiation in function is developing among farmers' strata through group farming operation—namely, differentiation in strata between farm leader and follower.

This is particularly true in group farming operation, which requires a high level of technique and intensive management. Farmers of the leader stratum extend their work volume in planning and management beyond their own farms. On the other hand, the work volume of farmers in the follower stratum naturally tends to decrease.

So far, on the surface there are practically no sales of agricultural land between these two strata and consequently practically no trend toward expansion of cultivated acreage. But in reality the farm-leader stratum is supervising the work of the follower stratum through group farming operations, and it seems important to give due attention to this functional differentiation. As to how it might develop in the future there is divergence of opinions.

Typical of the general opinion which evaluates group farming adversely is the claim that because the group farming functions with a village or sub-community as unit, it is an old, traditional group which only retards the economic differentiation of strata and the reduction in number of farmers.

Against such an opinion, as has been pointed out above, although group farming includes the existing large and small-scale farmers, functional differentiation into farm-leader and follower strata is progressing. This point can be verified by polls taken on the discontent of farmers against group farming (Table 3). This discontent can be classified into three categories: (a) because the management of the organized system is difficult, it is poor in efficiency, (b) there is an unbalance in burden of responsibility and benefit among participating farmers, and (c) it reduces the potentiality of development of relatively large-scale individual farm management. It is safe to assume that negative evaluation on these points comes mostly from large-scale farmers. That is, it certifies that the difference in ability within the group has

Table 3. Discontent with Group Farming Reported by Farmers.

Category	Proportion of farmers reporting			
	much	little	none	uncertain
	percent			
Inefficiency	6.2	36.4	38.3	19.1
Imbalance between burden and benefit	7.6	46.0	28.0	18.4
Inhibits development of large farms	7.9	31.7	41.7	18.7

emerged and the differentiation in function is progressing.

Because the role of the farm-leader stratum is large and the dependence of many farmers on leaders is increasing, the unbalance in burden and benefit has been taken up as a problem and there is a self-awakening of the farm-leader stratum to the fact that they are being sacrificed for the sake of the follower stratum—and those factors have been expressed as inhibiting the development of individual farm management. However, recently in many districts due recognition is being rendered to the expanded function of the farm-leader stratum and it has come to be considered proper to pay compensation for their guidance.

Accordingly, one prediction is that although group farming operations include many part-time farmers, it is conceivable that these small farmers will begin to commit the actual management of their property to leading farmers whom they trust. And this commissioning may be on an individual-to-individual basis or individual-to-group-leader. Whole farming operations or only major operations might be commissioned. At any rate, it can be predicted that the expansion of farm management scale will develop at first through the form of commissioning of management to farmers of the leader stratum.

Perhaps the highest merit of group farming operation is that it has been a spontaneous movement initiated by farmers for their own sake, whereas many other movements witnessed heretofore among farmers have been initiated, guided, and supported by the Government.

The reason group farming differs in strength and elasticity by districts is that each group of farmers has risen to the challenge of solving its own problems. It is the cumulative result of farmers' independent ideas on how to solve the inconsistencies in their situation. For instance, in districts where farmers have outside enterprises from which they obtain their main source of income and rice farming is a side job, the group rice farming operation is comparatively intensive. But in districts where rice farming is a main source of income the group farming operation permits a comparatively large degree of individual freedom.

Both respect for farmers' independence and the need for group activities are indispensable for the development of agricultural management. But those two often contradict each other. And each time such a contradiction arises it calls for self-solution, and the group farming operation is the application of such a self-solution. The writer highly evaluates the fact that most group operations have been independently conceived by farmers themselves and are highly elastic.

Various evaluations of group farming are presented above. But those points which are generally evaluated negatively are not judged as such by this writer. He evaluates highly a path toward progress which moves not in a straight line but on a zigzag course, reflecting an elastic and realistic attitude. In this sense we may say that group farming will inevitably help resolve agricultural structure problems.

Conclusion

Group farming is only one kind of group activity, but its scale is relatively large compared with other group activities because of including many part-time farmers. As stated above, it generally has achieved a high standard of land and labor productivity. This could only have come about if the formation of a stratum of farm leaders who can satisfy high standards of techniques and knowledge of rice cultivation had been progressing step by step. In fact, we must admit that the better farmers in Japan have quite a high level of scientific knowledge of rice culture.

In group farming, the division of farmers into two classes has been progressing little by little, and group farming has been managed mostly by the initiative of the leader class. Of course I cannot say that the formation of a leader class is clearly evident at the present time. To make Japanese agricultural mechanization successful in the future depends on successful organization of machinery utilization, however. Successful organization depends on the formation of a leader class.

In the situation where there is a steady increase in part-time farming, initiative for group farming or group utilization of machinery tends to come from public organizations—for instance the co-operative associations. Of course, we have some successful examples of this type, but I believe for the development of agriculture it is more desirable that the initiators should be farmers—the excellent-farmer group. One of the most important merits of group farming is, I believe, the formation of a leader class through the group activities of relatively large numbers of farmers. Through these activities differentiation of abilities among farmers becomes explicit. As a result, the class of persons admitted by all members to be leaders will be built up.

Mechanization is not aimed at labor saving alone, but at improvement of farming. For the improvement of farming, high ability of management is required. How to make group farming and group utilization of machinery successful depends on how to organize the group activities so that the formation of a leader class progresses naturally.

SOCIO-CULTURAL ADJUSTMENTS OF FARM FAMILIES AND RURAL COMMUNITIES IN THE PROCESS OF MECHANIZATION

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Japanese rural society has consisted of families on small farms, the basic units in the villages, whose life and production are undifferentiated. In such a society any change in the conditions of production causes a change in the way of life, and as result has an important influence upon the family structure of small farmers and also upon the structure of the *mura*, which is a combination of small farmers.

For example, mechanization of the means of production lessens the importance of the principle of self-sufficiency underlying the mura and results in production for market. Consequently, there occurs a reorganization both of the family structure of small farmers and of the mura structure on the new basis of production for market. Hence we have a great change in the essential social structure of Japanese villages. Nowadays, with the added influence of metropolitanization, we are facing the dissolution of villages and of farmers' families.

Though agricultural mechanization was undertaken in Japan after the war with great optimism, we have to face this deplorable phenomenon of dissolution of villages and farmers' families. At present we are still unable to find a solution for this unfortunate development. With this in mind, in discussing socio-cultural adjustments of farm families and rural communities in the process of mechanization we will divide the process into two phases.

The first is the period in which mechanization was optimistically accepted. The effects of mechanization in this period will be discussed with particular reference to the case of Niike mura, Takamatsu-cho, Okayama prefecture. The writer had the valuable experience of participating in observation of the process of mechanization in this mura, where he stayed for three years and studied at first hand various social effects caused by mechanization.

The second period in the process is the present one, in which agricultural development has reached a stage in which advances in mechanization cause many problems. To tell the truth, the effects of mechanization in the present stage are not yet established, and thus it is difficult to try to assess them.

Therefore, this report will only point out the problems caused by mechanization in the second period, and leave its assessment to the reader. To present, as objectively as possible, the problems Japan is now facing in her agricultural mechanization will contribute much to an understanding of Japanese rural society.

Social Effects of Agricultural Mechanization: the Case of Niike Mura, Takamatsu-Cho, Okayama Prefecture

Japan has had a remarkable change in rural society since the war. Mechanization, land improvements and the extended use of agricultural chemicals have brought about a great change in the method of production. Farming has been made less arduous. Increase in productivity has caused an increase in production for market, such as fruits or dairy products, as well as a rise in farmers' standard of life, both economic and cultural. Moreover, it has contributed much to farmers' self-realization as industrial men.

The natural result of mechanization in the method of production is a change in the social process both in villages and in farm households. In mechanization, the most remarkable development has been the increase in use of power cultivators and hand tractors. Mechanized cultivation changes only a part of farm work, but the influence of this change on the social process in villages and farm households has been great.

We once had hot discussion of the economic utility of the power cultivator. Some said that it was an example of over-investment, and others insisted that it did not have any great utility. Nevertheless, power cultivators and hand tractors became very popular with amazing speed. I think that such rapid and extended spread of the power cultivator can not be understood rightly by only considering its economic utility; there is in the power cultivator a certain social force.

Disregard of economic utility makes farm management insecure, but a power cultivator has other charms great enough to make up for the insecurity of management—the charm of speed, like that of cars and autobikes, as well as the charm of saving much hard labour.

Moreover, the attraction of the power cultivator is not only those charms but also its potential force to reform the old social process. Some people understand to a certain degree, though vaguely, this force latent in the power cultivator, and it is they who have pushed its introduction into farm management.

Mechanization in Niike mura

Here I will describe the influence of mechanization on the social process in the village, taking up the particular case of Niike mura. Niike mura is a rural village in Okayama prefecture, which is the most developed agricultural district in Japan. From Niike it takes forty minutes to Okayama city, thirty minutes to Kurashiki city and twenty minutes to Soja city. Niike consists of 24 farm households, all located on a sunny spot at the southern foot of a low hill. The size of management averages 69 ares, the maximum being 120 ares and the minimum 28 ares.

In 1950, the University of Michigan Center for Japanese Studies chose Niike as the object of its rural investigation, which continued for 5 years. The Center for Japanese Studies, as is well-known, aims to have a better understanding of the whole structure of Japanese society, and for its purpose picked out this village as a prototype for the study and analysis of Japanese rural society. The results of the investigation were published in 1958 as *Village Japan.*[1]

The investigations at Niike after 1959 were taken over by Japanese scholars. Sociologists, economists, historians and geographers cooperated in making a general investigation of Niike mura. It came about in this way. Robert B. Hall, first Director of the Center for Japanese Studies, became a representative in Japan of the Asia Foundation after the Center finished its investigation at Niike. He decided at that time that if the Foundation gave financial help to agricultural mechanization at Niike, and the process were studied from academic points of view, it would be useful both for the farmers and for the scholars.

Thus the Niike Mechanization Project was planned, and a grant of 3,300,000 yen was given to Niike mura with very favourable conditions: only half to be repaid, no interest, no payments for two years, and subsequent repayment in yearly installments over seven years. At the same time, a Niike Survey Committee consisting of eleven Japanese scholars was organized to study the effects of mechanization. Thus Niike mura, with its 24 households co-operating according to its own plan, began the experiment of mechanization and of improvement in living conditions and management.

Here I want to enter into details of the process of planning the mechanization at Niike. The Asia Foundation communicated directly to Niike mura, in August 1955, that it was ready to offer financial help for mechanization, and asked Niike mura if it would accept the offer. Niike of course accepted. Then a Mechanization Committee was organized at Niike and started making a plan for mechanization to submit to the Foundation. The first plan requested a total of 5,910,000 yen.

After the first plan was presented, however, various kinds of requests for improvement of living conditions and facilities for processing agricultural products were made by the villagers, so that a second plan, amounting to 8,020,000 yen in total, was made and presented to the Foundation immediately after the first one. But both plans were rejected by the Foundation, partly because they were considered to have been made not by all the villagers but only by some bosses of the village, and partly because the costs were too high.

Niike started remaking the plan and, after much reconsideration, completed the third plan, amounting to 3,300,000 yen. The third plan included only the cost for agricultural mechanization; the costs for better living conditions and for facilities for processing products were cut out. The much-reduced cost in the third plan reflected the people's overcoming their excitement at the unexpected offer from the Foundation, and showed that they had come to react reasonably to it.

The third plan was accepted by the Foundation, and a rough outline of the project was made up. The above-mentioned conditions for refunding the grant were decided at this stage.

The Foundation entrusted the Okayama Prefectural Government with responsibility for taking charge of machines and giving farm management guidance and supervision. The Prefectural Government organized a Management Committee, with the Governor as its chairman.

The first thing that the Committee did was to review and to improve the third plan. Those points in the third plan that were considered to be obviously uneconomic were improved, and the revised third plan was named the fourth plan. Niike approved the fourth plan, so this became the final plan, according to which mechanization at Niike was to be carried out. The Mechanization Committee was then dissolved and a Mechanization Association was established. This was the process by which the mechanization project at Niike was developed.

Next, I will point out three characteristics of this mechanization project.

First, it was direct and had no mediator—that is, the project was started as a direct contract between the Asia Foundation and Niike, with no mediator between them. Niike had not had this kind of experience before.

Second, it was intended to give equal benefits to all the villagers, for that was the only requirement the Foundation made. But what is equality? On this question the whole village divided into two contending groups. The well-to-do farmers and full-time farmers insisted on equality in proportion to the size of cultivated land under management—i.e., that the bigger one's cultivated land area, the more money one should receive. The poor farmers and part-time farmers insisted on mechanical equality—that everybody should receive the same amount of money. Thus self-interest brought the two groups into direct conflict.

Third, there was very rapid spending of the grant on machines and equipment. This was partly incited by incessant and keen approaches of salesmen of agricultural machines. People bought machines and equipment irresponsibly, simply because they wanted to have them, without making any long-range plan of mechanization or without making a careful plan for refunding the grant. As a result, the money was all spent in providing each household with small machines and equipment, and larger-scale mechanization was not realized.

Now these three characteristics caused great confusion in the village. And the confusion resulted in two undesirable phenomena. One is that some people came to get power and turned into bosses. The other is that the original plan of mechanization was not faithfully put into practice. The problem of bosses is discussed later. Here I will make a brief survey of the second phenomenon.

As mentioned before, the final plan of mechanization was the so-called fourth plan, which Niike approved, and by which the mechanization project was supposed to be carried out. The third plan had been based on the principle of individual independence, while the fourth plan was based on cooperation. Even in the third plan, common ownership was approved, but not any other kind of sharing. Contrarily, the spirit of sharing and cooperating permeated the fourth plan, in which not only common ownership but also joint working (by adopting a machine operator system or using a charge collection system) was emphasized.

Moreover, even common ownership was interpreted very differently in the third plan than in the fourth plan. In the case of a power cultivator, for example, people in Niike thought that members of a lineage should share its ownership, while the Management Committee considered that economic utility of a power cultivator should be the determining factor in deciding the form and range of common ownership.

This difference in basic principle between the two plans became more and more apparent and caused various kinds of tension in the village. In the outcome, the principle of the fourth plan gave way to the principle of the third plan.

Why was it so difficult to cooperate in the mura? Because in a mura a management unit is the *Ie* management, and the idea of cooperation based on freedom and independence was unacceptable to the Ie. If cooperation was unavoidable, then people would cooperate only among *Kabuuchi*, that is, members of a lineage.

In this way of thinking, economic utility was not the first thing to be considered. The fourth plan, however, contradicted this kind of thinking, and introduced into the mura a new way of thinking. On deciding what members should share common ownership of a power-cultivator, the villagers discarded the old way of grouping by Kabuuchi and adopted a new, economic way of grouping.

Changes in the Mura social order

At Niike the villagers were divided into three layers, upper, middle and lower, by the size of their cultivated rice-fields. The upper layer were those cultivating more than 80 ares of rice, the lower layer those with less than 50 ares. At the time with which we are dealing, those of the lower layer were part-time farmers.

In this mura there were no landlords, even before the land reform, and no old families. Therefore, how much rice-field a farmer had determined his social status, it being the determining factor in domestic economy and farm management. In such a mura, the order of the mura depended on the balance of power among the upper-layer villagers. We can say that the atmosphere prevailing among such villagers actually operated the mura, and that a leader in the mura was the person who rightly caught and understood this atmosphere.

However, as production for market advanced, the way of deciding one's economic and social standing by the size of one's rice-field came to lose its validity. People of the middle layer began to concentrate on producing other products for market, such as fruits, dairy products, rush-grass or poultry. Those who were successful with these products came to be well off, and their economic power became greater than that of the upper-layer farmers who depended only on rice-growing.

It is very important that in this project of mechanization Niike participated in the project from the beginning, making the plan of mechanization for itself. The village had never participated in such a big enterprise, taking all the responsibilities to carry it out. In Japan, all big enterprises had been planned by governmental offices. If some project was planned, in all cases either the Ministry of Agriculture and Forestry, or prefectural offices, or city offices or village offices gave a touch to the project and arranged it that it might be suitable for and acceptable to the mura. However, in the Niike Mechanization Project, the give-and-take relationship between the Asia Foundation and Niike was a direct one, with no filter between them. The mura did not know how to react to such a hitherto unknown direct approach.

People reacted either in confusion or in a vacant mood. But some of them were quicker than others in regaining themselves and making an adjustment to the new experience. They were the part-time farmers and farmers of the middle layer who had had some contact with the world outside the mura. Thus these farmers came to be influential. Also, people of the younger generation quickly understood how to react. So, in the mura there appeared three new rising powers: middle-layer farmers who were engaged in production for market, part-time farmers, and young people.

The time when the mura accepted the mechanization project was a kind of critical moment. In such a critical situation, who came to hold the leadership in the mura? It was Mr. O, who had a keen interest in production for market, by both his personality and his career. Mr. O was, as it were, a window opened to the outer world. People expected to get in contact with the outer world through Mr. O. Such expectations of people led to Mr. O's holding leadership, and he demanded power and became a boss.

But the critical moment was over when the grant amounting to 3,300,000 yen was divided and mostly spent. It was also the time when such tension as originated in greed was over. People were obliged coolly to consider how to repay the money. Then Mr. O, who was the leader in the critical period, lost his position. It now became important for the mura to regain its old daily atmosphere. People's desire to go back to the normal situation of the past naturally demanded the appearance of a leader who could work most satisfactorily under the old conditions. Such a leader was Mr. G, who represented best the ordinary daily aspect of village life. Mr. G, who was nicknamed "Dear Old Man", was a former member of the village assembly and came from the main family of the upper layer. He also had had the experience of working on land reclamation. His was the properly mixed character which was effective both inside and outside the mura. With his appearance as the leader, the atmosphere or harmony came back to Niike as if it were one great family, so that the peaceful daily routine started again in the village.

But the return of Mr. G as leader did not exactly mean the revival of the old order. It is true that the transfer of leadership from Mr. O to Mr. G was a transfer from a villager of the middle layer to one of the old upper layer. But in the process of change, the power of a leader was somehow weakened. Farmers engaged in production for market, part-time farmers and young people all moved to demolish the boss system, and their rising power brought success to this movement. Consequently, the leadership system of the Mechanization Association changed from a boss system to a group leadership system. Young people, part-time farmers and farmers engaged in production for market elected their representatives, who participated in the group leadership and came to have power equal to that of the upper-layer farmers.

The Mechanization Association which was organized at Niike in order to put into practice the project of mechanization had a very important role in the village. For it had the responsibility of achieving the goals of the project and also of repaying half of the grant. The results of the mechanization project would determine the economic and social rise or fall of each household.

Within the Association each layer of farmers and each household strongly insisted on its own interests, and a feeling of keen competition prevailed there, even though in the mura a peaceful daily life was considered to be most important. The Association was organized within the mura with all the villagers as members, so that the members of the Association were at the same time the members of the mura. Both practically and mentally, people tended to confuse the Association meeting and the village meeting and to regard them as the same.

In the management of the Association, the voices of middle and lower layer farmers, part-time farmers, branch families and young people became louder and more powerful. This phenomenon was directly reflected in the managing of the mura, so that the social order in the mura became flat, having lost its former pyramid structure.

Power cultivators and Kabuuchi

It is generally said that power cultivators "spread from windward to leeward." For the cheerful sounds of power cultivators operating to windward reach the ears of those down wind, who are cultivating either with cows or with hoes, and make them feel miserable. It is no wonder that they too want to have power cultivators.

Knowing this psychology of farmers, we can understand why farmers are so eager to get expensive power cultivators regardless of their economic utility. But by whatever motives it is introduced, a power cultivator insists on its own economic utility once it is introduced into management of the farm, and demands changes not only in management but also in human relations.

Here I would like to discuss the influence power cultivators had on Kabuuchi (*Dozoku*-clan), that is, members of a lineage.

The first plan offered by the mura proposed that Niike would buy five power cultivators, one for each of five Kabuuchi whose members would share its use. According to this plan, each power cultivator would cultivate 2.7 hectares of rice-fields.

Such usage of power cultivators was too uneconomical to be accepted by the Foundation. Niike was able to get only three power cultivators. In deciding by what grouping people would share a power cultivator, people at first thought of grouping by Kabuuchi. But grouping by Kabuuchi could not satisfy the condition that each power cultivator should cultivate about 4 hectares of rice land.

So it was agreed that people would form their own voluntary groups so that each of the three resulting groups would share one power cultivator and each cultivator would handle 4 hectares. Thus the Kabuuchi idea was discarded as a way of grouping people. This is an example of changes in the villagers' way of thinking: they gave up the old idea of grouping, taking into account the economic utility of a power cultivator. Indeed, the villagers were trained by the power cultivator to follow economic logic in their thinking.

Independence of part-time farmers

The increase in the number of part-time farmers in Niike was remarkable, although this was a general tendency in all villages. Before the mechanization project started there were 13 part-time farmers at Niike, but there were 23 after four years. The cases in which the farm operator himself was a part-time farmer increased from 6 to 8.

Farm operators who were part-time farmers had formerly been inferior to full-time farmers in techniques, machine equipment, and the amount and quality of labor. These farmers had depended on their main families or other influential farm managers both in production and life.

The mechanization project counted a part-time farmer as an independent farm manager and treated him as the equal of a full-time farmer. So the project gave the part-time farmer an opportunity to mechanize his farming and to become independent in life and management.

In the part-time farm households, because men were engaged in some other work, the daily work of farming had been done by women and old people, and hardest work during the busiest farming season was done with the help of their main families. With the installation of machines, however, part-time farmers came to manage all the basic field work such as plowing by laboring on Sundays. Thus, their dependence on their main families became less and less.

At the same time, mechanization also brought a change of farm operators in the main families, resulting in less intimate and more distant relationships between the main families and the branch families. With this double influence of mechanization, part-time farmers became established as independent farm managers.

As a result, the status of part-time farmers rose in the mura, with their already established economic power. Tension arose between the full-time farmers and the part-time farmers and caused disagreements on many points. With regard to repayment of the grant, for example, they thought differently: the part-time farmers insisted that one's responsibility for repayment should be in proportion to one's real property such as house or land, while the full-time farmers insisted on equal responsibility for repayment.

They disagreed, again, on the method of improving the ways of village life. I will take up one example. At one time the villagers got interested in simplifying wedding and funeral ceremonies. In order to save a lot of money that was spent on funerals, one idea proposed was that they should provide altar ornaments for common usage. But the proposal was given up because of strong opposition from the part-time farmers. The part-time farmers' reasoning was as follows: The form and cost of a funeral should be decided by the social life of each household and by the social status of the dead man and the chief mourner. The circle of part-time farmers' social life spreads to towns, and they closely associate with town people, sometimes more closely than with villagers. For such part-time farmers it is difficult to participate in funeral arrangements which are based on the village life. It invades individual freedom, they insisted, to force the standard form of funeral upon every household.

The above-discussed tensions and differences between full-time farmers and part-time farmers were not peculiar to Niike, but are universally seen in Japan. I think that this problem is the most basic and typical of all the problems the mura is facing in the torrent of urbanization.

Change of farm operators

As the tie binding families weakened and as each family tended to be independent, there was an inevitable change within families. Before mechanization the young had been under the leadership of the old. Once mechanization started, the young came to hold the leadership and command the old. Ploughing or puddling by power cultivators became too difficult for the old, who then came to be engaged in some light and unimportant work. Gradually, the young came to have the right of managing the farm.

I will explain why it is only 'gradually' that the young began to manage the farm. In many cases, only a part of management, usually an unimportant part, was at first placed in the hands of the young. If the family started a new enterprise such as fruit growing or dairying, this new enterprise was committed to management by the young.

If this new type of production for market was successful, the relative importance of rice-field management in the hands of the old was greatly lessened. Moreover, when the revolutionary element of mechanization was introduced into rice-field management and cows were gotten rid of, the basic ground of the old people's right of management was shaken.

The advancement of mechanization thus fatally affects the old men's right of management as well as the importance of cows. Likewise we can understand that the less the dependence on human and animal labor or on the old men's experience and knowledge, the easier it is to transfer the right of management from the hands of the old to those of the young.

Let us consider the roles in a particular farm activity, the hulling of rice. In hulling rice, workers are needed for five different roles—an operator of the huller, a carrier of rough rice, a measurer of the hulled rice (*masudori*), a carrier of hulled rice, and a filler of straw-bags with the hulled rice.

The operator of the huller controls the whole operation, so that he appears to be the most responsible man. But in fact, the measurer of hulled rice, the masudori, who sits in front of the rice sorter and measures rice flowing down out of it, is the most important person, and the farm operator takes this role. The farm operator examines the quality of flowing rice, remembering the growth of rice on each piece of land and also the labor and technique devoted to growing it, and thinks about delivery, and the next year's plan. The masudori at the same time measures his total rice harvest for the year. So you sometimes ask a non-member of the family to operate the huller, but never to be the masudori. That role is always taken by the farm operator.

In such an activity as hulling of rice, which requires the old men's experience and knowledge, as in the traditional management of rice production, the old men's authority remains unshaken, and the right of management is not transferred from the old to the young. But when a new enterprise develops that is managed by the young, and its relative importance increases, the transfer of the right of management progresses, though imperceptibly.

Incidentally, the transfer of the right of managing production does not always mean the transfer of the right of managing the domestic economy of the family. The old fathers, even though they have handed the right of farm management to their sons, do not give up the right of managing the domestic economy or the whole household. If a new farm operator just follows the ways his father established, there won't be any trouble, but any change in the routine results in tension between the old generation and the young one. If the old father, who holds the family's purse, insists on the old way of management or the old way of farming, the new farm operator's right of management can not be complete. If the new farm operator, however, can achieve the same results as his father or do even better, it will not be difficult for his right of management to be fully exercised.

Change in the Combination of labor

To understand the impact of mechanization within the family let us examine in more detail the traditional family structure and how it changes over the course of the family cycle. In the Japanese village, a lineal family is most common and typical. Usually it consists of two couples, of two generations, and these couples make two nucleuses which are organically combined not only in family living but also in organizing agricultural labor. Labor in the family farm consists, except in some unavoidable cases, of a diad: that is, husband and wife or father and son, who cooperate with one another or divide work between them. This is the most common form of the combination of labor.

When the father is the farm operator and his son is also an adult, father and son form the basic labor combination. At such a time, the father's authority as a farm operator is strongest. The labor force under the father's leadership consists of mother, son, and son's wife, plus the second son and the third son, if there is more than one son. The combined labor power in such a case reaches the maximum for one lineal family.

Now mechanization has the power to change this form of combination of labor power. Though the core of labor before mechanization was the vertical combination of father and son, it now moves to the horizontal combination of son and son's wife. In the basic ploughing work, for example, the father's role is to plough with the help of draft cattle, after which the son and other members of the family do the crushing and further soil preparation. After mechanization, however, the son's operation of a power cultivator becomes the core of the work, the father's cows becoming useless. Then it is the son's wife, not the father, who helps the son in his work, and the father completely loses his role in the ploughing work. This phenomenon changes the labor diad from the vertical combination of father and son to the horizontal combination of son and son's wife. It also quickens the transfer of the right of farm management from father to son, and at the same time consolidates the position of the son's wife.

In short, we can summarize the change in the combination of labor power in this way. At the start of the family cycle there is one couple. In that case, the horizontal combination of husband and wife is the basic combination of labor power. But when their son grows up, the vertical combination of father and son becomes the basic combination of labor power. Then, when the right of management is transferred from father to son, the horizontal combination of husband and wife again becomes the basic combination of labor power.

This cycle of change in the combination of labor power corresponds to the cycle of change in family composition. Mechanization quickens this cycle of change.

Rise and fall of individual farm households

The mechanization project in Nikke involved the farmers of each layer in production for market and encouraged their tendency toward part-time farming. But the mechanization project, though it aimed to establish cooperative management, could not fully achieve this aim, nor could it break down the small individual-management system. Here is the limitation of mechanization in this mura. I think that it is also a limitation inherent in the character of the small power cultivator. Each individual management unit finds it more difficult to fight against the wave of commodity economy, and becomes more uneasy the more strongly it insists on its independence.

The farmers of this mura engaged in four kinds of production for market: fruit growing, dairying, poultry farming and rush grass weaving. Each farm household began to engage in one or two of these four, while it was basically engaged in the production of paddy rice, wheat and rush grass.

In this process, the rise and fall of the middle layer was most conspicuous; some of them were successful and rose to be upper-layer farmers, while some had the bitter experience of failure.

What kind of farmers succeeded? Those whose households had enough capital and in which the right of management was smoothly transferred from father to son. For smooth transfer means that there is a simple and open human relationship in the household. There, labor power can be combined with cheerful cooperation and efficiency. Only on such a basis can hard labor be performed without destroying human relationships within the family. In other words, only the household in which there is peace and harmony can organize the hard work of farming efficiently and achieve improvement in farm management.

The Influence of Urbanization

Urbanization and the village

We can understand villages only in relation to cities. Both villages and cities are parts of the whole society. They are only different expressions of our human way of life. So villages and cities are closely related to each other in their ways of life. We should understand, therefore, that urbanization means, not that villages turn into cities, but that both cities and villages enter the next stage of development. Let us therefore examine the meaning of urbanization and how urbanization affects villages.

There are three stages in the process of urbanization. The first stage is *urbanization* in its narrow sense, and its characteristic is the concentration of population. The second stage is *metropolitanization*, in which the city population overflows into the surrounding territory, resulting in the formation of a metropolis. The third and last stage is *megalopolitanization*, that is, the formation of a megalopolis, which consists of several metropolises. Within a megalopolis, villages and cities are mixed together, the fences dividing them disappearing, and a new local community of higher level comes to exist.

In megalopolitanization, villages change so greatly that their unique structure collapses. Originally, villages were places where farmers were engaged in agriculture. In other words, agriculture, farm households and farmers—all these three were contained in villages. But when housing, commerce and industry invade villages, villages turn into residential quarters, shopping districts or factory sites. Then agriculture, by combining with commerce or industry, changes into agribusiness or agro-industry. Also, farmers begin to work outside the villages and turn into part-time farmers.

The characteristic of the Japanese small farmers, as I have said, was that their life and production were undifferentiated. Now, under the influence of metropolitanization, a metropolitan way of life spreads all over the country—over cities, farm villages, mountain villages, fishing villages; life in those villages comes very close to that in cities. In spite of that, the management of farm production does not become industrialized or commercialized, so that the difference in income between city dwellers and village farmers increases. In short, life in villages becomes less different from that in cities, but farmers' incomes become lower than those of city dwellers. To solve this contradiction, farmers become interested in working in another part of the country (*dekasegi*) or in becoming part-time farmers. Naturally, the farms face a problem of labor shortage, which they seek to solve by mechanization.

Mura and individual management

An individual farm household does not exist on its own. It is a unit of a cooperative system called a *mura*. That is, individual farm households in combination make up a mura and thus carry on their life and production. An individual farm household can exist only where a mura exists. There are 5,340,000 farm households in present-day Japan, but one should not think of Japanese agriculture as consisting of those 5,340,000 farm households. The farm households are gathered into 140,000 mura, and it is of these that Japanese agriculture really consists.

The mura has three important functions: managing the land within the mura, managing the agricultural production, and managing its residents. To perform these functions, the mura collects money from the villagers.

Our next concern is to see how mura management changes under the influence of urbanization, and also what problems the mura comes to face.

First, urbanization increases the number of residents in the mura who are not engaged in farming, and at the same time changes the mura into residential quarters, shopping districts or factory sites. Consequently, many cars, taxis and trucks begin to run on the narrow farm roads and destroy them. Moreover, water for irrigation comes to be polluted with sewage from houses and factories.

When the land of the mura is thus destroyed, it becomes very difficult to manage it. For even if the mura collects more money from its villagers for managing the land, the money can never cover the expenses, as farmers become fewer in number through urbanization. Also, the labor for managing land was previously shared by the farmers, but those who can share in this labor decrease in number because they turn into part-time farmers or begin to work outside the mura.

As almost all the healthy men and young people leave the mura, the heavy burden of managing land comes to rest on the shoulders of old people, women and children. Recently, even women have begun to be engaged in part-time work outside the mura. Thus, it becomes impossible for the mura to do one of its fundamental functions, that is, to manage its land..

Now, let me repeat what I have explained. An individual farm household exists within the frame of management of a mura. With the recent remarkable tendency towards part-time farming, the average income of farm households has risen and since 1966 has become higher than that of city workers. Of the farm family's income, non-agricultural income—wages, fees and salaries—constitutes an increasing part. By becoming part-time farmers, they become better off; their increased income enables them to introduce machines into their farm management; by mechanization, much labor is saved; the saved labor seeks employment in non-agricultural industry. Thus 'mechanization' and 'the increasing tendency to turn into part-time farmers' are chasing each other in a cycle. We can say that individual farm households are in the middle of this cyclic process.

At the same time that it is becoming impossible for the mura to manage its land, individual farm households are becoming better off and their standard of life is rising higher and higher. If this phenomenon continued indefinitely, the mura management would come to an end and individual farm households would cease to exist. Without mura management of farm roads and water for irrigation, individual farm households can not really exist, because these are the basic functions of the mura. Here is the reason why farmers so anxiously ask for basic land improvement. They eagerly want the government to undertake basic land improvement projects because it makes their managing of land much easier.

Through urbanization, the numbers of non-farmers and non-agricultural elements increase in the mura, and the non-farmers' right to speak, or their influence, becomes more strongly established. This increase in non-farmers checks the development of agriculture. Although the non-agricultural elements within the mura increase, the mura continues to exist in spite of its failure to manage its land. As a result, the non-agricultural elements become increasingly influential. That is to say, in order to maintain the mura, the money for mura management is collected even from non-farmers, which makes non-farmers' right to speak stronger and thus weakens the mura. In short, the mura, to maintain itself, has to adopt means the consequence of which is further disintegration of the mura as a basic agricultural institution.

Basic land improvement is necessary for mechanization. At the present stage, it is impossible for individual management to accomplish basic improvement of land. It must be done by some unit larger than a mura. It is generally done by a land improvement district office, of which each mura is a unit.

Land improvement projects depend greatly on each mura's right to speak. Officers of the land improvement district office are elected from each mura in proportion to the size of its cultivated land. Thus the influence of a mura in the land improvement office is affected by the size of its cultivated land. The success or failure of mechanization is decided by the conditions of land improvement. The mura with the strongest representation at the office can carry out a land improvement project at the time and in the way most suitable for its conditions, arranging the contents of the project as it likes.

For such a mura, it becomes easy to carry out mechanization projects, and for the villagers of such a mura it becomes easy to turn into part-time farmers. Then the level of the residents' income in such a mura increases.

But, as I have discussed, it finally becomes impossible for such a mura to manage itself. And meanwhile the tendency to leave farming accelerates.

ECONOMIC AND ENGINEERING ASPECTS OF MECHANIZATION OF RICE HARVESTING IN KOREA

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Harvesting of crops is the most important and delightful part of the farming season. However, such machines as the tractor and the power tiller are usually introduced earlier than harvesting machinery. Harvesting requires the most advanced machines, such as the large combine which makes possible reaping, threshing, winnowing, and tagging by a single machine. It would be possible to raise the mechanized level of farming with the distribution of this large combine.

In Korea most of the crops are harvested with the traditional hand sickle. The busiest part of the farming season and the peak of labor are during the rice harvest in the fall and the barley harvest in the spring. In order to ease the labor peak it is necessary to mechanize the harvest with a more advanced manual harvester or a power harvester.

The necessity to mechanize farming is an important subject not only in Korea but also in many other East Asian countries. Therefore, in order to achieve the best method of harvest mechanization, different kinds of harvesters were studied, their economic and engineering aspects were analyzed, and an investigation was made of their present status and future prospects.

Harvest in Korea

Paddy field cultivation is the major aspect of Korean farming. In 1969 the total area of paddy fields was 1,293,709 hectares (ha.), that of upland fields was 1,036,709 ha. There were 2,546,244 farm households with an average of 6.21 people per house and a rice cultivation area of 50.8 are (a.) and an upland field area of 40.7 a., for a total of 91.5 a. of cultivated land per farm.

Of all the cultivated area, 1,208,045 ha. is for paddy-grown rice and 21,640 ha. is for upland rice. For the winter grains, 446,326 ha. is for barley, 503,128 ha. for naked barley, 154,182 ha. for wheat and 16,024 ha. for rye, a total of 1,119,662 ha. Harvesting of these crops is chiefly done with the traditional hand sickle. The 1969 harvest inventory reported 10,000,000 hand sickles, 10,000 manual harvesters, 391,692 manual threshers, and 33,878 power threshers.

During the rice harvest the rice is cut, dried loosely in a drained paddy field, and then tied in bundles. (If the field is undrained, the rice is bundled after cutting and then gathered on the foot path.) In most cases the manual thresher is used; however, recently the power thresher is coming into use.

In the upland crop harvest in June, barley is harvested with the hand sickle. Rice planting also is done during this season. The rainy season begins at the end of June or early in July. Figure 1 shows the labor peak in June and July, the barley harvest and rice planting period, and in October and November, the rice harvest and barley seeding period.

Recently the number of farms and the farm population have been greatly reduced. This phenomenal decrease has resulted in a shortage of farm labor. During the past five years farm labor costs have increased 500 percent. As Figure 2 shows, the labor cost in 1981 is expected to be 2,305 won, three times that of 1971.

Irrigation, drainage, and rearrangement of arable lands are preconditions for achieving farm mechanization. At present the area of rearranged arable land is 135,000 ha., but 458,000 ha. more will be rearranged by the completion of the Third Five Year Economic Development Plan, bringing the total to nearly 600,000 ha. or 50 percent of the total paddy area.

Upon realization of the Third Five Year Plan, the farm sector will be supplied with 5 HP or 10 HP power-tillers and other harvesting machines.

Types of Harvesters

Many kinds of harvest machinery have proved practical in foreign countries. However, some kinds are difficult to use profitably in Korea. Various kinds of useful harvest machinery

Fig. 1. Monthly labor input.

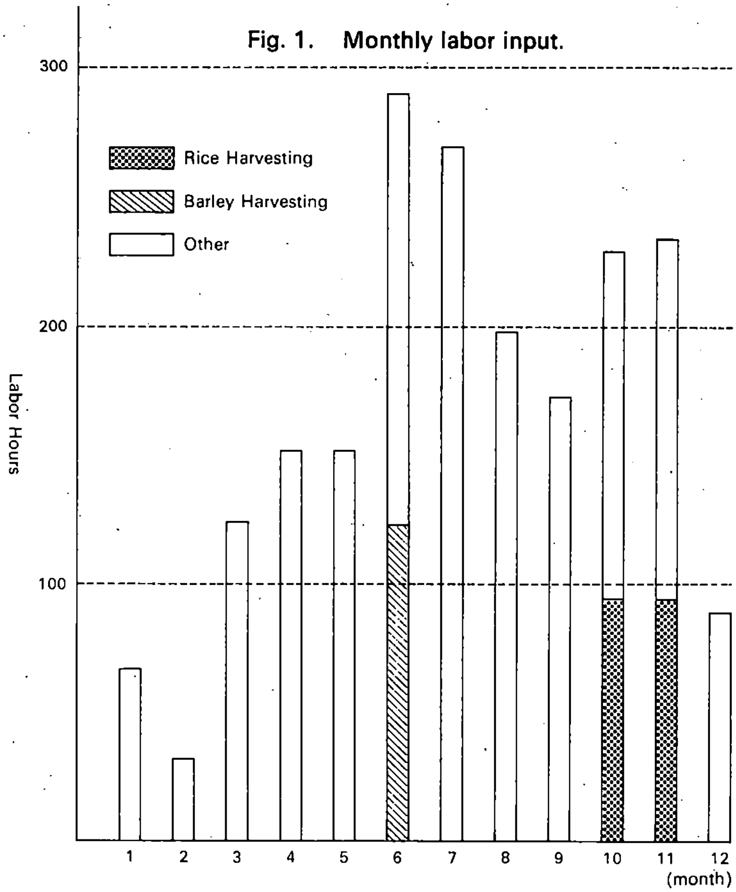
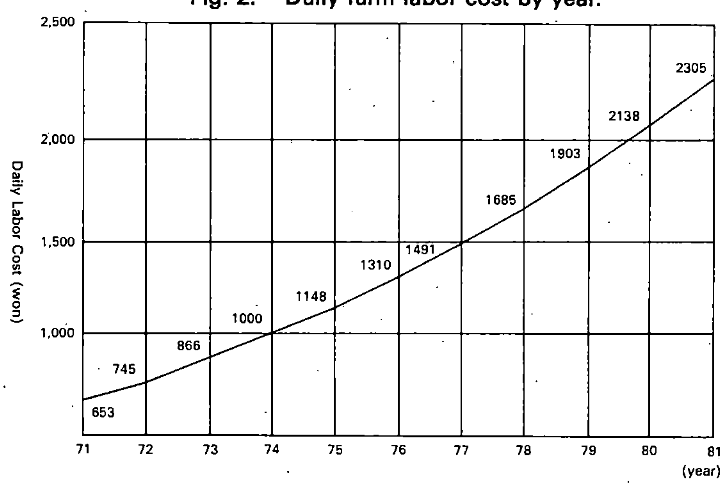


Fig. 2. Daily farm labor cost by year.



in Korea are as follows:

Manual harvester. There are two kinds of manual harvesters. Both have V-shaped blades. In one kind the workman pushes the harvester forward, and in the other kind he pulls it toward him.

Reaper. The reaper cuts the rice and lays bunches of the cut rice down on the paddy.

Binder. The binder is more advanced than the reaper. It has an attachment which ties the rice into bundles and lays them down on the paddy. There are three kinds: one-, two-, and three-row harvesters.

Manual thresher. Generally, two people work the manual thresher: one keeps the revolving drum turning while the other feeds the rice straw into it for threshing. Most of the threshers used in Korea are of this type.

Semi-automatic thresher. This is larger than the manual thresher. Except for the use of motor power instead of man power, the working method is almost the same.

Automatic thresher. This thresher threshes, separates the grain from the chaff, and bags the rice all automatically.

Combine. The combine used in Korea is somewhat different from the large combines of Europe or America. The functions of the reaper and the automatic thresher are performed in one operation. The cut rice is fed automatically into the thresher. This small, special type of combine, called a self-threshing type combine, is newly developed. Compared to the large combine, this combine has several advantages. It is more suitable to Korean farm conditions, as less grain is lost, and it is less expensive.

Economic Analysis of Mechanization

Specification of data used (see Table 1).

1. *Purchase price*. At present, the sickle, manual harvester, manual thresher, and semi-automatic thresher are produced in Korea. The prices used for these machines in our calculations are the average market prices. Because the reaper, binder and combine are not yet mass-produced, we use estimated prices based on the foreign market. Constant prices are assumed in this analysis.

Table 1. Data for Economic Analysis.

Machine	Purchase price	Dura-bility	Depre-ciation cost	Main-tenance cost	Capac-ity	Opera-tion per day	Labor	Fuel	Fuel con-sumption
	(won)	(year)	(won)	(won)	(a/hr)	(hr)	(won)		(1/10 a.)
Combine	700,000	8	70,000	42,000	6	6	1	gasoline	3
Binder	400,000	8	40,000	24,000	6	6	1	gasoline	2
Reaper	300,000	8	30,000	18,000	10	6	1	gasoline	1
Automatic thresher	130,000	8	13,000	7,800	10	6	4	gasoline	3
Semi-auto. thresher	90,000	8	9,000	5,400	8	6	6	kerosene	2.5
Manual thresher	12,000	5	600	720	4	8	8	kerosene	—
Push-type harvester	4,600	4	230	276	3	8	1	—	—
Pull-type harvester	2,300	4	115	138	3	8	1	—	—
Sickle	150	1	0	0	1	8	1	—	—

Additional assumptions:

1. Labor cost—700/day in 1971; in later years as shown in Fig. 2.
2. Fuel cost — (a) Gasoline won 31/1.
   (b) Kerosene won 18/1.
3. Interest—15%year.
4. Working days — (a) harvest 15 days.
   (b) threshing 20 days.
5. Labor for binding—(a) with reaping by sickle or mechanical reaper—2 hr./10 a.
   (b) with reaping by push- or pull-type harvester—3 hr./10 a.

2. *Durability.* For the power machines, durability is assumed as 8 years. This was based on foreign experience and theoretical operating-hour capacity.

3. *Depreciation.* For the power machines yearly depreciation is assumed to be 10 percent of the purchase price; for the manual machines, 5 percent.

4. *Maintenance.* The annual maintenance cost is assumed to be 6 percent of the purchase price.

5. *Capacity.* Estimates are based on data obtained from actual field tests in Korea. Figures are rounded off to the nearest whole number.

6. *Net operating hours per day.* For the power machines, net operating hours per day is assumed to be 6 hours. This excludes time needed for preparation and transportation. For the manual machines, 8 hours is assumed.

7. *Labor cost.* The labor cost has been estimated at 700 won per day in 1971, and thereafter as shown in Figure 2.

8. *Interest.* The interest rate of the Bank of Korea is 20 percent and that of the National Agricultural Cooperative Federation is 15 percent for funds to be used for farm management. However, interest rates outside the banks range from 36 to 60 percent. A low interest rate of 9 percent is available in special cases. In this analysis 15 percent was used.

9. *Binding cost.* Manual binding is estimated to require 2 hours per 10 ares when reaping is done by sickle or by power reaper, 3 hours when reaping is done by either the pull-type or the push-type mechanical harvester.

Table 2. Combinations of Methods Compared in Step 3 of Economic Analysis.

Group	Cutting	Binding	Threshing
I	Sickle	Manual	Manual Thresher
II	Manual harvester	Manual	Automatic thresher
III	Reaper	Manual	Automatic thresher
IV	Binder	Binder	Automatic thresher
V	Combine	—	Combine

Analytical procedures

Analysis of comparative cost of different harvesting methods is carried out in three steps:

1. *Cutting and binding*. Comparison of costs when cutting is done with the sickle, the manual harvester, and the reaper (binding in each case being done by hand), and when the combined operations are done mechanically with the binder.
2. *Threshing*. Comparison of costs with the manual thresher, the semi-automatic thresher, and the automatic thresher.
3. *Cutting, binding and threshing*. Comparison of costs using combinations of the above methods and when all three operations are done simultaneously by the combine. The five systems compared are shown in Table 2.

These comparisons are made, first, in terms of annual costs of rice harvesting alone, for varying areas, assuming the 1971 wage rate. Then the effect of increasing wage rates is analyzed, and estimates are made assuming extension of mechanization to barley harvesting. Finally, the effects of reduction in machinery prices are analyzed, and estimates are made of the acceleration of harvest mechanization that would be possible with government subsidization of purchase of machinery.

Annual costs at 1971 wage rates

Results of step 1 are shown in Figure 3. Cutting and binding cost at 1971 wage rates is lowest using the manual harvester, next using the sickle, then using the reaper. The binder has the highest cost.

In threshing (step 2), cost relationships vary with cultivated area (Figure 4). The break-even point is estimated to be 2.4 ha. For smaller areas the manual thresher is least costly, for larger areas the automatic thresher. The semi-automatic thresher is intermediate in cost in either case.

For the combined operations (step 3), the system combining the sickle for cutting and the manual thresher (Table 2, Group I) is cheapest for cultivated areas of less than 1.9 ha. For larger areas, the manual harvester and automatic thresher (Group II) is the most economical (Figure 5). A break-even point between the sickle and the reaper (Group III) occurs at 5.8 ha. Both the binder (Group IV) and the combine (V) have much higher costs

Fig. 3. Cutting and binding cost vs. cultivation area.

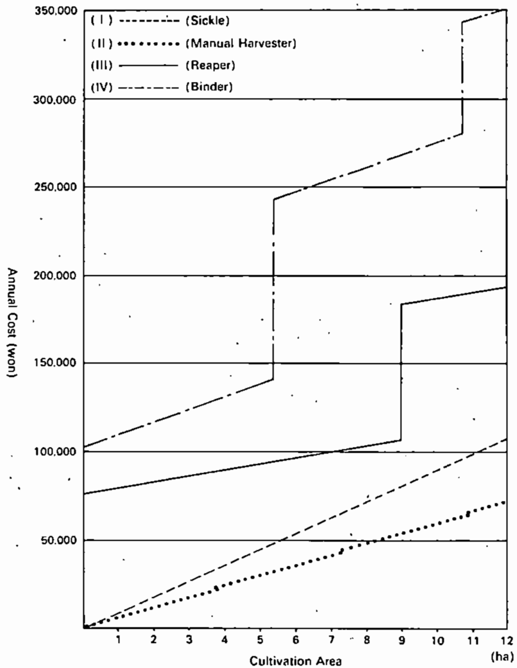


Fig. 4. Threshing cost vs. cultivation area.

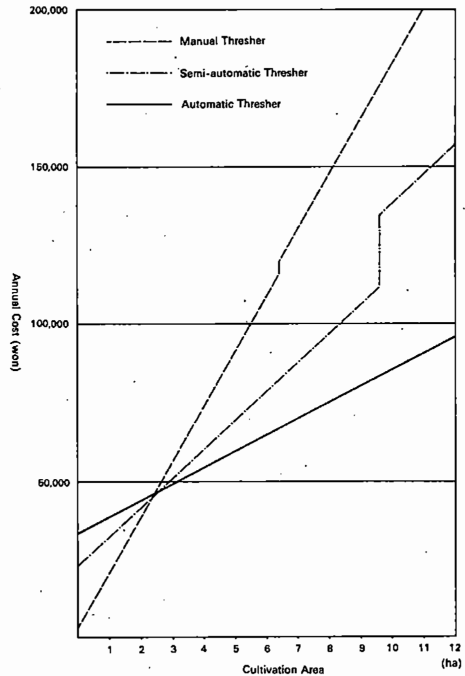


Fig. 5. Harvest cost vs. cultivation area.

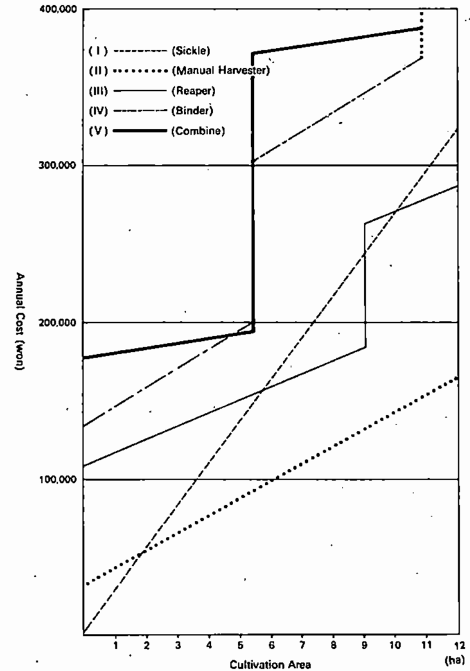


Fig. 6. Cutting and binding cost vs. cultivation area.

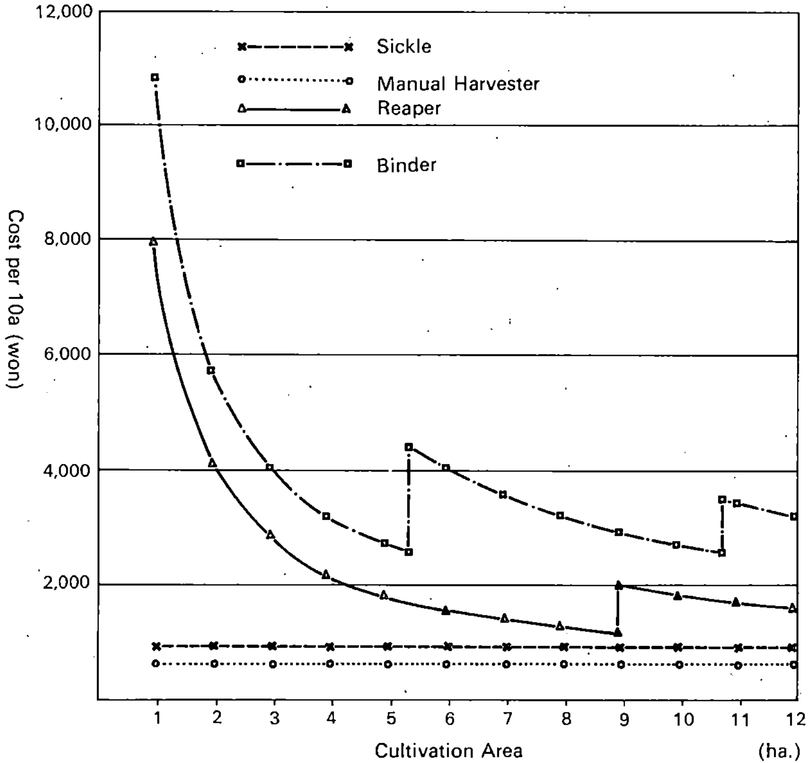
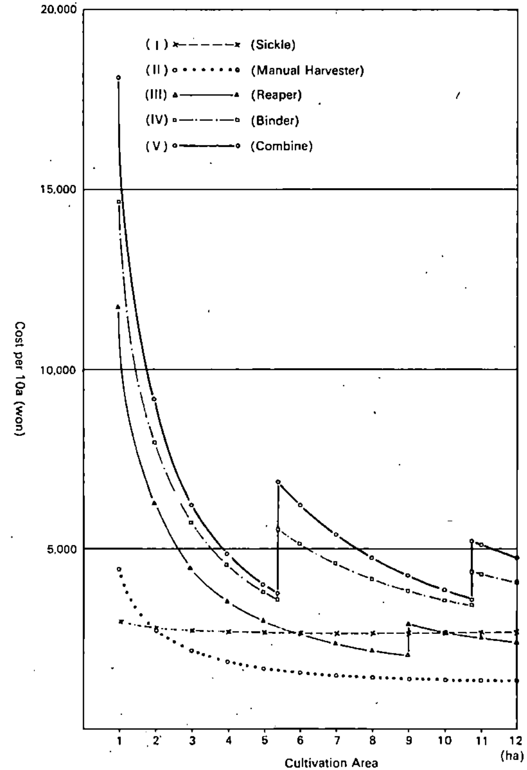


Fig. 7. Harvest cost vs. cultivation area.



than the other methods throughout the range of areas analyzed, at the 1971 wage rate.

The same relationships in terms of cost per 10 a. are shown in Figure 6 and 7.

Effect of rising labor cost

As discussed above, wage rates of agricultural labor are expected to continue to increase, and this will affect the economics of substitution of mechanical power for man power in harvesting. Therefore, the effects of rising labor costs on the preceding cost comparisons have been estimated, in cost per 10 a. Results are interpreted in terms of a time scale using projected wage rates increasing to 2,500 won per day by 1982 (Figure 2).

Cutting and binding. As Figure 8 shows, the manual harvester is the most economical until the labor cost becomes 2,300 won (1981). After this, the reaper is the most economical method. Comparing the sickle and the reaper, the reaper seems to be more profitable from the 1,000-won point (1974). The binder does not become more profitable than the sickle until the labor cost becomes 2,500 won (1982).

Threshing. As Figure 9 shows, the more labor cost increases, the greater the cost advantage of the automatic thresher. The semi-automatic thresher does not prove as economical as the automatic. The manual thresher is the least economical.

Total harvesting cost. Among the five harvesting systems, that based on the manual harvester shows much lower cost than that using the traditional sickle (Figure 10). The reaper becomes the least costly system at a wage rate of 2,300 won per day (1981), the combine at rates somewhat above 2,500 won. Comparing mechanical harvesting with use of the sickle, the reaper is more economical when the daily labor cost exceeds 400 won, both the binder and the combine when it exceeds 1,000 won (1974). The cost advantage of the reaper over the binder is 1,400 won per 10 a. in 1971 and 1,200 won in 1981.

Effect of including barley harvesting

So far the calculation of the harvesting cost has been limited to rice harvesting. There is a presumption that if a machine could be used in the harvesting of several grains, the fixed cost

Fig. 8. Cutting and binding cost vs. labor cost.

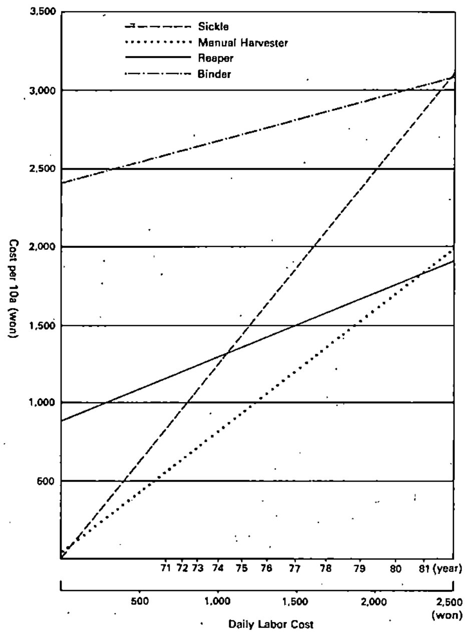


Fig. 9. Threshing cost vs. labor cost.

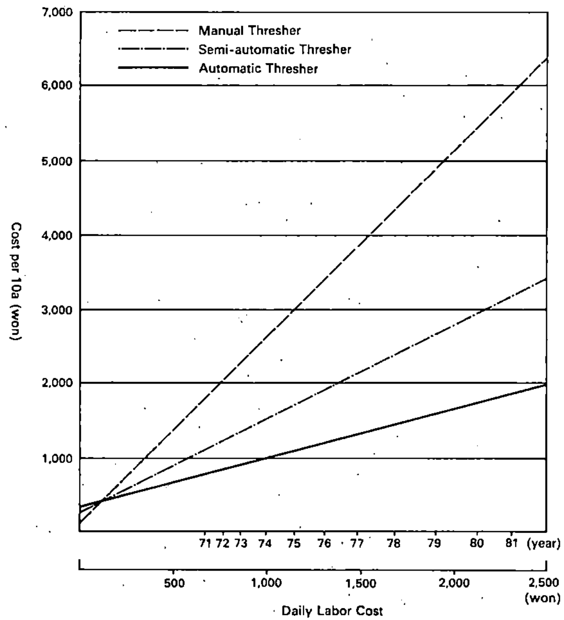
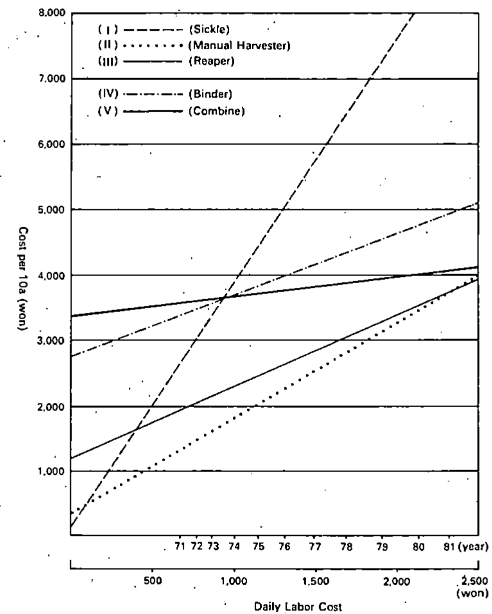


Fig. 10. Harvest cost vs. labor cost.



could be spread and the cost per 10 a. would be decreased.

However, it is impossible to use machines for barley harvesting now, because barley and barley field conditions are not suitable for this. Most barley harvesting is at present done with the sickle; the reaper, binder, and combine are not used.

The major grain grown in Korea is rice, and most cultivated paddy is used for rice, while most of the barley is grown on upland. There are almost no upland irrigation or drainage facilities, and land rearrangement has not yet been done. Therefore it is difficult to use machinery in barley cultivation. Barley is planted in wide spaced furrows, and between the rows other crops are often planted. Also, the stalk of barley is too short to facilitate the use of machinery. Cultivating methods must be changed if machinery is to be used profitably in barley harvesting.

However, we have estimated the effect on costs if 50 percent of the barley were harvested by machine in 1976 and 100 percent in 1981.

Machine harvesting of 100 percent of rice and 50 percent of barley in 1976. When the daily labor cost is 1,250 won, the fixed cost goes down by one third. In this case, machines show more profitable results than the sickle (Figure 11). Among the harvesters the manual harvester is the most economical, the sickle is least economical, and the reaper, combine and binder show intermediate economic results. If this assumption could be realized, machine harvesting would be more profitable than the sickle.

Machine harvesting of all barley as well as rice in 1981. When it is assumed that the labor cost is 2,250 won in 1981, and if the area of barley cultivation is equal to the area of rice cultivation, machine harvesting proves the most profitable (Figure 12). The most economical machine is the combine, next the reaper. Cost with the manual harvester and the binder is a little higher, but still much less than with the sickle.

Effect of reduction in prices of machines

To determine what reductions in price would be necessary to make the various machines competitive in harvesting cost with the sickle and the manual harvester, costs have been calculated assuming machinery prices at varying percentages of their actual

Fig. 11. Prediction of 1976 harvest cost per 10a. (assumes 1,250 won per day labor cost and 50% increase in harvest area through dual-purpose use).

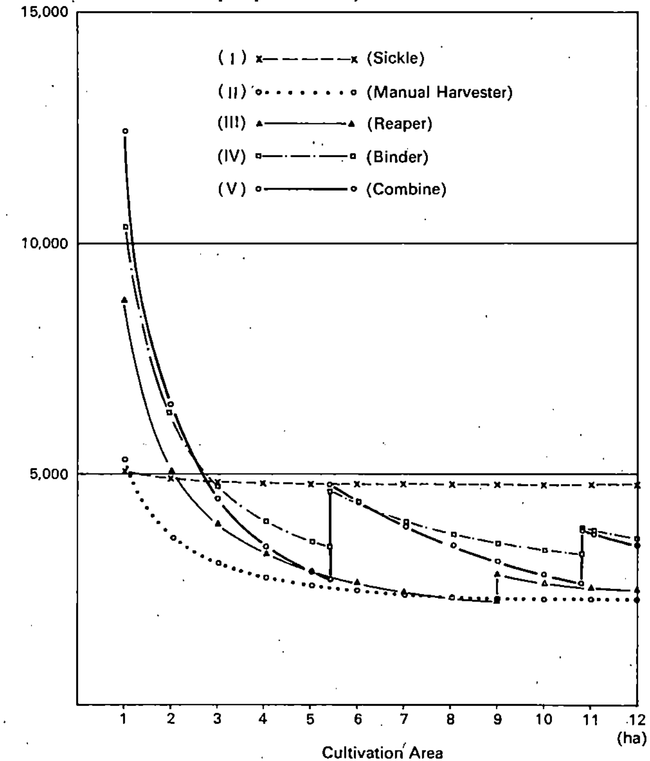
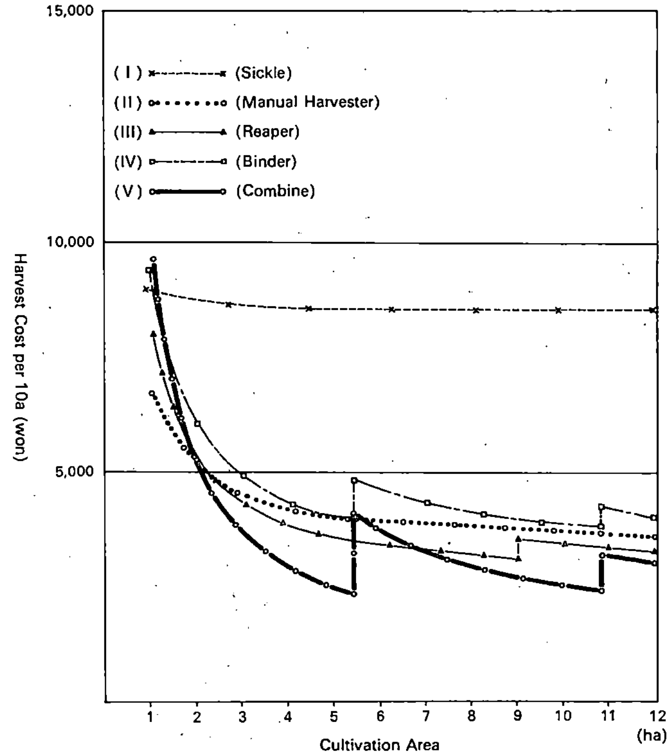


Fig. 12. Prediction of 1981 harvest cost per 10a. (assumes 2,250 won per day labor cost and 100% increase in harvest area).



prices. Results are as follows:

Cutting and binding. The price of the reaper would have to be reduced to 67 percent of its actual level, and that of the binder to 10 percent, to enable them to match the sickle in cost of cutting and binding at 1971 wage levels (Figure 13). Compared with the manual harvester, the reaper price would have to be reduced to 30 percent of its actual price, and cost with the binder would be greater than with the manual harvester even if the binder were supplied free.

Total harvesting cost. To match the sickle in total harvesting cost including threshing, the combine price must be cut to 74 percent of its actual level, the binder to 62 percent. The reaper, however, is more economical than the sickle, at optimum scale of operation, even at its full price. To match the manual harvester, both the combine and the reaper must be reduced to 32 percent of actual price, while the binder is again more costly even if supplied free (Figure 14).

Effect of government subsidy for purchase of harvesting machinery

Since 1961 the government has been providing subsidies for the purchase of farm machinery. Here we analyze the effects of government subsidies of 33 and 50 percent of the purchase price in accelerating the adoption of harvesting machinery.

Subsidy of 33 percent. With a subsidy of one third of the machine price, the reaper and combine would become more economical than the manual harvester four years sooner and the binder two or three years sooner (Figure 15). When the labor cost becomes 1,700 won per day (1978), the combine would be the most economical method of harvesting.

Subsidy of 50 percent. With a subsidy of one half of the purchase price, the combine becomes more economical than the manual harvester in 1975, seven years earlier than with no subsidy. With this rate of subsidy the combine is more economical than the sickle even now (Figure 16).

Discussion of the Harvesters

The five kinds of harvesters are now discussed in greater detail in light of the preceding economic analysis.

Fig. 13. Cutting and binding cost vs. machine price.

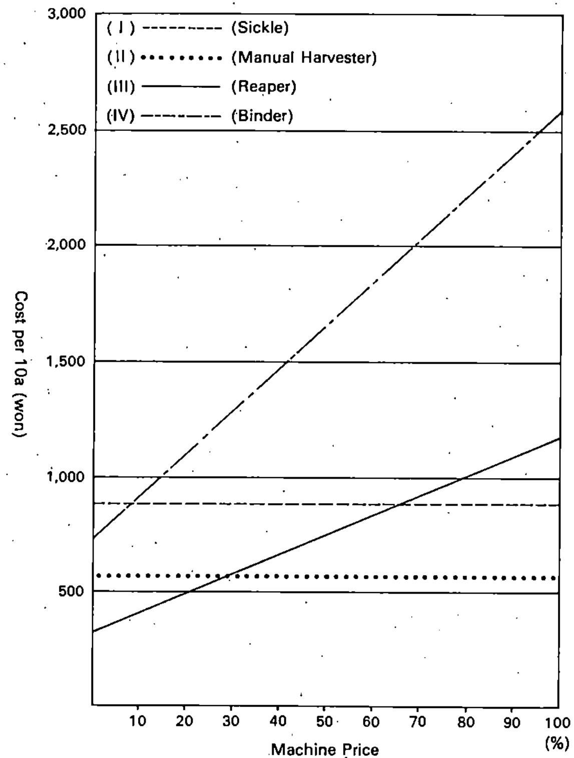


Fig. 14. Harvest cost vs. machine price.

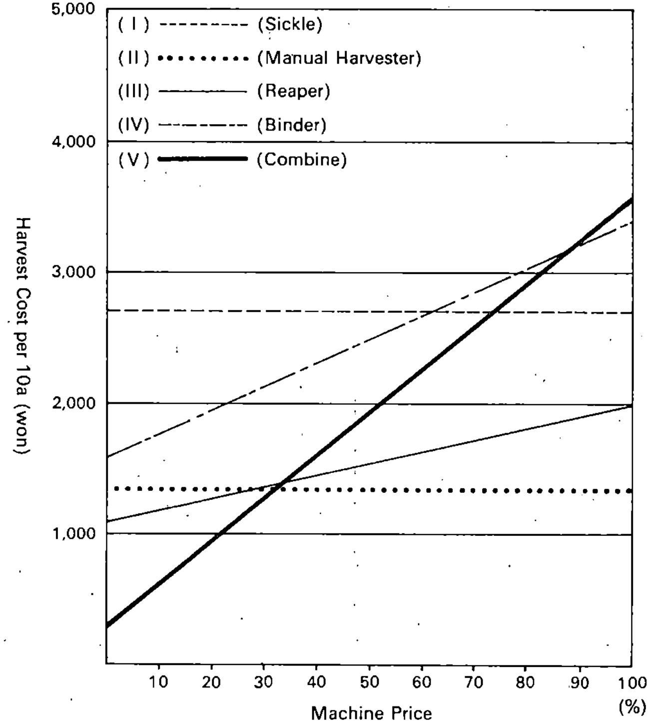


Fig. 15. Prediction of 33 % subsidy harvest cost vs. labor cost.

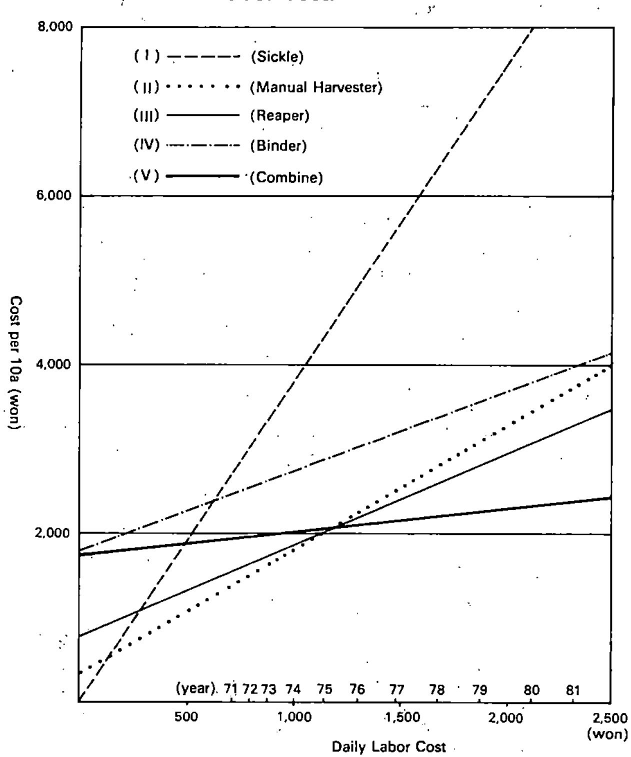
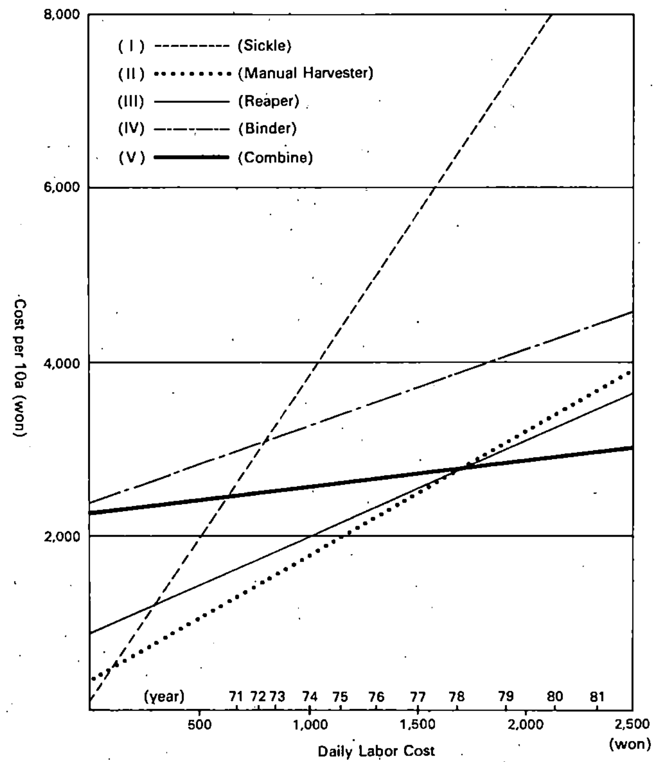


Fig. 16. Prediction of 50% subsidy harvest cost vs. labor cost.



Sickle

At present, most crops are harvested with the traditional sickle. Even though the sickle is inexpensive and the Korean farmer is quite proficient with it, labor efficiency is low and the working posture is not very healthy, as farmers must work in a bending position. Therefore, a more efficient harvester must be substituted for the sickle. When the manual harvester is used, the cost per 10 a. is 306 won less than with the sickle. It is expected that as labor costs increase, the reaper, binder, and combine will all become more economical than the sickle.

Manual harvester

There are two kinds of manual harvesters. As Table 1 shows, the capacities of the two harvesters are the same, but the price of the push-type is almost twice that of the pull-type. Therefore, there is more possibility for the pull-type to be supplied to farmers.

With the manual harvester it is possible to work standing, and reaping can be done three times as fast as with the sickle. From the economic analysis, and given the projected yearly labor costs, it seems that the manual harvester will be the most efficient method until the year 1981. For a small-scale farm in Korea, the manual harvester is the most suitable one until the reaper is supplied in 1976 and the combine in 1981. But its weak point is the difficulty in harvesting barley. It can only be used for harvesting rice.

The manual harvester is now produced in Korea. (The most important part, the blade, is made from imported material.) Its structure is simple and it weighs only 1 kilogram.

Technically, it would be possible to harvest all the rice throughout the country with 330,000 manual harvesters. But to replace all the sickles on farms, each farm would need to possess one or two manual harvesters; thus 2,500,000 to 5,000,000 harvesters would be needed throughout the country.

Reaper

The reaper, next most profitable after the manual harvester, is to be supplied to farmers beginning in 1976. Its costs are expected to be lower than the sickle. By 1980 the reaper will become more economical than the manual harvester. Harvesting costs with the reaper are estimated to be 1,200 won less per 10 a. than with the binder 10 years from now.

The reaper has the advantage that it can also be used for barley harvesting. Because Korean farms are small in scale and are just starting to mechanize, it is desirable to manufacture simple machines at cheap prices. In a country like Korea, where crops are dried in the fields during the dry fall weather, the reaper is a very suitable harvester.

The reaper is the simplest power harvester. If good quality material is used for the blade and the reaper is manufactured accurately, it will be easy to produce in Korea. Samples are being manufactured in Korea now. The reaper is now disappearing in many foreign countries, but it is the machine best suited for Korean farms. If all rice were to be harvested with the reaper, this country would require about 133,000 reapers. It is calculated that the reaper should be supplied after the manual harvester and before the binder.

Binder

In foreign countries, the binder is a very popular machine. It combines the operations of cutting and binding, saving much labor. It will become more economical than the sickle for these operations around 1980. With threshing expenditures included, it will be more economical in 1975, but by that time the combine will be even more economical.

The reason the binder is more popular is that the price of the combine is very high, and since it threshes directly without drying, a dryer is also required. The binder has the advantage of field drying. Also, the uniformity of bundle size makes use with the automatic thresher easier and more convenient.

The reaper is more economical than the binder, but the reaper requires hand binding. Thus when the farmer becomes richer, he usually buys a binder rather than a reaper. For instance, in Japan the binder is more popular than the reaper. However, it is interesting to note that Japanese farmers started with the large, three-row binder, and next the two-row binder, but recently the small, inexpensive, one-row binder has become popular. One can see that farmers need low-price, convenient, simple machines.

In Korea the binder is expected to be supplied after 1980. The one-row binder seems to be a promising machine. It uses a binding attachment on a reaper. Samples are being manufactured in Korea now.

If all paddy fields were harvested with the binder, it is estimated that 220,000 binders would be needed. The government plans to supply 30,000 in 1981.

Combine

The combine is a very efficient machine for cutting and threshing rice. However, the price is high and it threshes directly without drying. Therefore, a dryer is necessary. The combine will become more economical than the sickle or the binder by 1975 and than the manual harvester or the reaper by 1980.

With a government subsidy of one third the purchase price, or if 50 percent of the barley is harvested with the combine, it would be the most profitable of all the harvesting machines at the wage rates projected for 1978.

The Korean government is now supplying the new rice variety IR-667. In order to prevent the shattering that is common with this variety, the government is planning to supply the combine now.

Korean factories are planning to manufacture the combine, but it is the most difficult to produce among the harvesters. As the combine works in the paddy field, the weight must not be too heavy, and vibration is a problem. To harvest all the paddy fields with the combine, 222,000 combines would be needed. The government plans to supply 30,000 combines in the next 10 years.

Problems of Purchasing Harvesters

Farm income

Even if a machine is profitable, a farmer must possess the economic purchasing power to buy it. Purchasing power may come from increase in farm or in non-farm income and increase in savings.

Of course total farm income must increase, but it cannot be expected that many farmers will be able to purchase farm

Table 3. Savings and Farm and Non-farm Income in Korea.

(won)

Year	Savings	Farm income	Off-farm income
1967	14,159	149,470	33,111
1968	27,999	178,957	42,023
1969	37,342	217,900	50,800

machinery just from their farm income. The income from farm products is just too small. In foreign countries, expensive farm machinery is often purchased from income external to the farm. Even if farm or off-farm income increases, capital to purchase machinery must remain after other expenditures for farm management have been met. Table 3 shows that it would take many years for an average Korean farmer to be able to purchase machinery, as savings and incomes are just too small relative to machinery prices.

The labor cost of farming

Labor cost is a very important factor directly affecting the purchase of machinery. Our economic analysis has shown that rising labor costs will make it profitable and economical to use machinery. Labor costs are directly related to farm population and number of farm households. The projected farm labor costs in Korea were shown in Figure 2. The combine would be the most economical machine when the labor cost becomes 2,300 won per day in 1981.

Prices of harvesters

In Korea, prices of machines are very high compared to farm incomes. This makes it difficult for farmers to purchase machines. As economic analysis shows, the price of a machine greatly affects the fixed cost. The prices of machines in Korea are also very high compared to those in foreign countries. It is hoped that mechanized manufacturing processes and mass production can lower the price of machinery.

Table 4. Government Subsidy for Farm Machinery Purchase, 1961–68.

(In percent of price)

Year	1961	1962	1963	1964	1965	1966	1967	1968
Government subsidy	60	57.8	56.5	41.8	46.0	39.1	40.5	33.8
Loan	—	—	4.2	—	—	—	4.0	28.5
Farm share	40	42.2	39.3	58.2	54.0	60.9	54.5	37.7

Government aid

As a big sum of money is required at once, it is difficult for farmers to purchase machinery. Also there is difficulty in practical supply. Table 4 shows the government subsidy program for 1961–1968. Figure 15 shows that the combine would become the most economical machine in harvesting cost per 10 a. by 1978, given a 33 percent subsidy.

Table 5 shows the estimated proportions of financial support required in purchase of machines in order to make their harvesting costs equal to that of the manual harvester. In the case of the reaper 70 percent support would be needed in 1971, 47 percent in 1976, but only 5 percent in 1981. For the binder, 66 percent would be required in 1981, for the combine 12 percent.

Subsidies at these levels would require huge government expenditures if more than a few persons were to receive them. A further weak point is the dependence of farmers upon the government for the purchase of machinery.

The government proposes to shift from subsidies to loans in helping farmers buy machinery. Farmers will be required to repay the loans over the period of life of the machines. If the machines reduce farmers' costs, this method should be successful. To make this policy effective, the government must provide the loans to farmers at low rates of interest.

Joint purchasing and joint operation

The ideal arrangement is for each farm to have its own machinery. However, farm machines are too expensive for most Korean farmers to purchase them individually. Furthermore, the

Table 5. Estimated Subsidies Required to Make Harvesting Costs with Machines Equal Those with the Manual Harvester

(In percent of price)

Year	Reaper	Binder	Combine
1971	70	100	68
1976	47	92	47
1981	5	66	12

capacity of a combine or a binder is 5.4 ha. per year, and that of a reaper is 9 ha. per year. This is a vast area compared to the cultivated area of one Korean farm household. Therefore it is recommended to purchase machinery jointly for joint operation.

Condition of cultivation area

The cultivation area must be properly arranged and irrigation and drainage must be in good condition for machine utilization. At present, 130,000 ha. have been rearranged, and 450,000 ha. will be finished according to the Third Five Year Economic Plan. This project must be continued, and emphasis must also be put on upland field development.

Selection of kinds of machines

The selection of machines suited to the purchaser's needs is an important problem in farm mechanization. Attention must be paid to farm location, purchasing power of farmers, cultivating methods, species of crops, size of machine, and efficiency. Under actual conditions in Korea, it is difficult for farmers to choose machinery. Because Korea is at the beginning stage in farm mechanization, there is a limited variety of machines.

Cultivating methods and improvement of species

It is difficult to operate power harvesters when crops lodge. It is impossible when the angle of the crop is below 25 degrees. Accordingly, the species must be improved and selected carefully if machinery is to be used in harvesting.

If stalk length is below 60 cm it is impossible to use a binder, and if over 120 cm the working efficiency is decreased. Especially since the Korean barley species has a short stalk, it is difficult to use power harvesters. A taller species must be substituted for the shorter one.

For machine harvesting of barley or wheat, the harvesting time must be speeded up to prevent loss and the field must be without ridges in order to make machine operation easier.

Dryers and other machinery

Because the combine threshes directly without drying the grain, there is need for an artificial dryer. Because the moisture content of rice is about 25 percent, if the rough rice from the combine is not dried at once the rice will deteriorate. Thus other kinds of machinery must be supplied in the process of rice harvest mechanization.

Training

As new machinery is supplied, training courses will be required. Farmers are generally conservative in accepting new kinds of machines, so the government must train them to operate the machines correctly.

Summary

In Korea, the Third Five Year Economic Development Plan (1972–76) is in progress now. In that plan, farm mechanization is considered an important part of Korea's agricultural modernization.

An urgent problem to be solved is to decrease the labor peak in June and July, when farmers are busy harvesting barley and transplanting rice, and in October and November, when farmers harvest rice and plant barley. Labor reduction during these two periods could be achieved by farm mechanization.

The total area of rice fields is 1,200,000 ha. and that of barley is 1,100,000 ha. It takes 120,000,000 hours to harvest rice with sickles. If sickles were replaced by power harvesters more than 100,000,000 hours of labor could be saved. Mechanization will eventually be essential also in barley harvesting.

There is a tendency for farm employment to decrease by 1.2 percent annually. It is expected that labor cost will increase to 1,250 won per day in 1976 and to 2,250 won in 1981. Because of the shortage of labor and the rise in labor cost, farm mechanization is essential.

According to the economic analysis, the manual harvester and power thresher will be most profitable until 1981; after 1981, the reaper will become most economical, and after that the combine. Therefore the manual harvester should replace the sickle before power harvesters are adopted.

If the mechanization of barley harvesting becomes possible. the harvesting cost per 10 a. will be reduced and it will be economical to use power harvesters three to five years earlier.

For the mechanization of barley harvesting, upland fields must be rearranged and the species of barley must be changed to one more suitable for mechanized harvesting.

Of the three kinds of harvesting machines, the reaper has the lowest harvesting cost. The cost per unit area when using the binder is about 1,400 won higher, as the machine price and the overhead cost are higher. It would be more profitable to supply the reaper following the manual harvester, as the reaper has a simple structure, low price and high working capacity.

The binder is the most popular harvester in several foreign countries. It should be supplied after the reaper in Korea. Among the three kinds of binder, the one-row model would be most suitable for Korean farm conditions.

The combine will eventually become the most economical machine, but because its price is so high it is expected to be supplied only after 1980.

The manual thresher and semi-automatic thresher must be replaced by the automatic thresher, because of its low threshing cost per unit area.

The prices of farm machines are quite high relative to the prices of farm products. Machine prices must be cut down by the aid of the government. If the prices were cut down by one third, the machines could be bought three years sooner.

Development of suitable power harvesters for Korean farms must be promoted. The government must provide technical and financial support for improving farm machinery manufacturing.

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CONTRIBUTION OF ECONOMIC RESEARCH TO RICE MECHANIZATION IN WEST MALAYSIA WITH SPECIFIC REFERENCE TO THE MUDA IRRIGATION SCHEME

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West Malaysia consists of about 50,700 square miles of land of which about 22 percent is presently arable. The total area under cultivation amounts to 7,062,000 acres of which rubber, with 4,457,000 acres, is the major crop, accounting for 63 percent. This is followed by rice, with 1,003,000 acres or about 14 percent; and oil palm, with 578,000 acres, or 8 percent. The remainder is under coconut and miscellaneous crops.[1]

The General Position of Rice in the West Malaysian Economy

Rice is thus West Malaysia's second most important crop in terms of acreage, and although the proportion of rice in relation to total cultivated area is small, it nevertheless presently accounts for about 84 percent of the area under annual crops.

The contribution of rice to West Malaysian Gross Domestic Product (GDP) has never been large, being on the average about 4 percent. Its importance is far outweighed by rubber, tin-mining, forestry and the rapidly growing industrial sector. In terms of the proportion of the population dependent on rice cultivation, however, the rice sector is of major importance. The 1960 Census of Agriculture showed that the total number of farm households in that year was 572,430. Of this number about 142,950, or 25 percent, were reported as specialized rice farms, and 133,480, or 23 percent, as mixed farm (part rice and part other crops).

Rice farms in 1960 accounted for 48 percent of all farms and provided a means of livelihood for about 1.32 million persons.

In projections for 1970, rice cultivation was estimated to provide full or part employment to about 0.508 million persons, or 19 percent of the labor force of the country.[2]

Recognition of the importance of the rice sector to the West Malaysian economy has been explicit in the nation's development plans since independence in 1957. Rice policy is characterized by two specific objectives:

(1) To increase the incomes and standards of living of the rice farming population through increases in the productivity of rice farming.

(2) To increase domestic rice production to achieve as high a degree of self-sufficiency in rice as is economically feasible.

Consistent with the above policy objectives, there has been a rapid increase during the last decade in the crop acreage under rice as a result of public investment in irrigation and drainage projects designed to enable double-cropping in existing rice areas.

The total area double-cropped with rice in 1962 was 49,110 acres. This had risen by 1969 to 238,130 acres, an increase of 485 percent over the seven-year period.[3] The trend of expansion of irrigation and drainage facilities in existing padi areas is being maintained and by 1974 it is expected that 570,000 acres, or 57 percent of the area under padi in West Malaysia, will be under double-cropping.

In these intensive rice areas of West Malaysia mechanization has made considerable headway even prior to double-cropping and here, because of certain physical and economic constraints associated with the introduction of double-cropping,[4] mechanization has come to assume major significance.

The Muda Irrigation Scheme

The Muda Irrigation Scheme, Malaysia's largest agricultural development project, provides a significant area of study into the contribution of economic research to the rice mechanization process in Malaysia. The Scheme, situated in the coastal plains of the States of Kedah and Perlis in the northwest of West Malaysia, is designed to enable double-cropping in 260,000 acres, or 26 percent of the existing rice land in West Malaysia. When fully double-cropped by 1974, it will account for 33 percent of the annual crop acreage under rice.[5]

The Muda Agriculture Development Authority has been established at the regional level and is charged with the responsibility of planning and the implementation of agricultural development in the Scheme.

A brief description of the salient features of the Scheme is relevant here. Stretching 40 miles from north to south, and more than 10 miles east to west, the Scheme covers an area with a long tradition of single-crop rice cultivation. Agriculture in the Scheme is characterized by the predominance of rice, which accounts for about 77 percent of land use.

Rice cultivation forms the main source of income and economic activity for over 50,000 farm families with an estimated on-farm population of over 325,000 persons. Farm sizes average 4.0 acres. The majority of farms are characterized by complete dependence on rice.

Mechanization is not a new feature of rice cultivation in the Scheme, but has traditionally been associated mainly with land preparation. A tractor contractor system utilizing 4-wheel tractors, presently running up to 77 brake horsepower, has been in operation for about 10 years. This is supplemented by considerable numbers of farmer-owned 2-wheel walking tractors. In 1966, four years before the introduction of double-cropping, about 40 percent of the rice land in the Scheme was ploughed with tractors.[6]

The Contribution of Economic Research to the Mechanization Process

Promotion of rice mechanization in the Muda Irrigation Scheme is a basic objective in the double-cropping implementation plan of the Muda Agriculture Development Authority (hereafter referred to as the 'Authority'). Economic research into the mechanization process, then, has come to assume considerable significance to the planning and implementation of policies relating to rice mechanization. The specific contributions of economic research are to be found at several levels:

(1) A fundamental issue is the establishment of an economic justification for mechanization to support the Authority's active promotion of mechanization in the Scheme. Simultaneous with

this is the identification of critical operations of the rice production process which must be mechanized given specific economic and physical constraints of double-cropping. Establishing an economic justification for mechanization is especially important in view of arguments that mechanization will lead to rural unemployment in the face of supposedly unlimited supplies of rural labor.

(2) The next stage involves an analysis of forms of mechanization already prevalent in rice cultivation. The function of this type of research is two-fold: first, to determine the relative economic suitability of various types of machines already being used extensively or being presently field-tested in the Scheme; second, to identify economic problems associated with the utilization of these conventional forms of mechanization, given particular physical and economic constraints arising out of rice double-cropping.

(3) Finally, having identified economic problems associated with conventional forms of mechanization, the issue for economic research becomes the determination of the ideal form of mechanization. This stage of the analysis necessarily involves the application of both economic and engineering criteria.

Justifications for Mechanization: the Constraints of Double-Cropping

The situation before double-cropping

Except for land preparation, all other operations in the rice production process have traditionally been performed by manual labor and simple implements. Single-cropping in the 260,000 acres included in the Scheme was characterized by a lack of uniformity in cultivation schedules.

Dependent entirely on rainfall, cultivation seasons typically began in the northern portion of the scheme, where early rains were normally experienced. The season gradually spread south with the rains. The entire rice area then underwent approximately a three-month staggering of cultivation operations.

Typically, cultivation would start with the onset of rains in July/August and spread south until September/October. As a result of this, the subsequent operations of rice production were similarly staggered throughout the Scheme, and harvesting would normally be staggered through January, February and March.

Single-crop rice cultivation in the Scheme has traditionally been associated with a high degree of hired-labor utilization. A Farm Economic Survey undertaken in 1966[7], four years before the introduction of double-cropping, indicated that about 79 percent of the farmers used hired labor to perform all or part of the various operations of rice production.

The actual pattern of hired-labor demand is characterized by its seasonality, the degree of demand for hired labor varying considerably throughout the cultivation season according to the per acre labor requirement of particular cultural operations. This is indicated in Table 1.

Hired labor is of considerable significance in the performance of cultural operations normally associated with high labor requirement. While the utilization of hired labor itself is nothing abnormal, what is of considerable interest is the actual proportion of hired labor and family labor in the performance of these various cultural operations.

Table 1. Percentage of Farms Reporting Use of Hired Labor for Various Cultural Operations in Rice Production.

Cultural Operation	Percentage of Farmers Using Hired Labor
1. Nursery preparation	14.8
2. Field preparation (excluding tractor ploughing)	52.6
3. Transplanting	58.6
4. Fertilizer and insecticide application	6.2
5. Weeding	9.2
6. Harvesting and threshing	78.8
7. Winnowing	9.5

Source: *Farm Economic Survey of the Muda River Project, 1966,* Ministry of Agriculture and Cooperatives, West Malaysia, Kuala Lumpur, Sept. 1967.

Table 2. Proportions of Hired and Family Labor in the Labor Force in Kubang Sepat, Season 1966/67, by Cultural Operations.

Cultural Operation	Percentage Hired Labor	Percentage Family Labor
1. Land preparation (excludes tractor ploughing)	19.6	80.4
2. Transplanting	92.3	7.7
3. Weeding	19.9	80.1
4. Pest control	5.1	94.9
5. Harvesting and threshing	89.8	10.2

Source: *Labor Survey of Kubang Sepat, Season 1966/67,* Dept. of Agriculture, Kedah, March 1969 (mimeograph).

A study of labor requirements undertaken in an area of the Scheme prior to the introduction of double-cropping yielded the interesting results shown in Table 2. Both the high overall degree of hired labor utilization and the significance of the hired labor component in the performance of several cultural operations point to a scarcity in the supply of on-farm family labor.

Various studies have substantiated this. The average size of the farm family is 5.5 persons.[8] The major factor determining the size of the farm family work-force, however, is the age-sex distribution of the farm household. A study undertaken in the Scheme[9] revealed that only half of the average farm family were in the productive age group (defined as 16–55 years for males and 16–50 years for females). Further, owing to factors such as off-farm employment, only 42 percent of the farm family actually worked on their farms.

In relation to the average farm size of 4 acres, the size of the average farm family work force is small, and this has been a major factor contributing to the heavy demand for hired labor.

In one cultural operation, transplanting, traditional reasons that are not yet fully understood have acted to reduce the available labor by half and thereby aggravate the demand for hired labor. Transplanting is done almost entirely by women. The labor utilization survey quoted in Table 2 showed that 97.4 percent of the total labor utilized for transplanting, and 100 percent of the labor hired for this operation, consisted of females.

Although males do appear in the labor force for transplanting (2.6 percent), they are relatively underemployed and generally perform only carrying of seedlings from the nursery to the field. The dependence of transplanting on female labor is further aggravated by the fact that women, for cultural reasons, generally lack geographical mobility and do not generally travel far from their village.

There is substantial evidence to indicate that even with the relative lack of uniformity in the cultivation season in single-cropping, the region has traditionally been labor short, particularly during transplanting and harvesting. The labor shortage problem has dictated some farming decisions. A common practice to reduce dependence on hired labor during single-cropping has been to plant rice varieties of differing maturity periods, which leads to a staggered harvest on the farm, or to plant the same variety at different times, which staggers both planting and harvesting.[10]

A further factor indicative of the insufficient supply of local labor during peak seasons of labor demand is that historically, harvesting, the most labor intensive operation in rice production, has been heavily dependent on migrant labor from Kelantan, a state on the north-east coast of West Malaysia, and Pattani, a province in south-east peninsular Thailand. The average annual size of this migrant labor force for the nine-year period 1961–69 was 11,624 persons and the average duration of stay in the Scheme was approximately 2 months.[11]

Identification of critical operations for mechanization

The introduction of double-cropping in the Scheme is characterized by two major factors which have increased the demand for labor in a region already experiencing seasonal labor shortage during single-cropping. This has resulted in an increase in labor costs, which in itself does not seem to have created any significant increase in labor supply, thereby leading to serious problems of labor shortage during periods of peak labor demand.

The first factor is the imposition of a uniform and stringent cultivation schedule to enable the growing of two rice crops a year. Specifically, the time periods for land preparation, planting and harvesting the crop over the entire Scheme have been reduced from the traditional 3 months to approximately 6 weeks for each of these operations. This cultivation schedule has been found necessary for the maximum utilization of water resources in double-cropping,[12] but its stringency has given rise to problems of labor shortage and associated increases in labor costs.

The second factor contributing to increased labor demand is the introduction of one or two short-term rice varieties of uniform maturation period to enable two rice crops a year. Staggering of labor demand in individual farms through the single-cropping practices of planting rice varieties of different maturation periods is no longer possible. Not only do farmers have to follow specified planting and harvesting schedules, but also the irrigation design does not permit farmers to individually exercise water control on their own farms.

Given these constraints of double-cropping, the size of the labor force required for the whole Scheme will have to be at least doubled if reliance is placed on labor-intensive methods for the implementation of double-cropping. In addition, the shortened periods of intense labor demand associated with the double-cropping schedule result in correspondingly shortened periods of employment opportunity for labor. Labor demand becomes more highly seasonal than in single-cropping. Unless wage rates rise proportionately, these shortened periods of intense labor demand will not support labor at adequate levels of income, and this acts as a disincentive particularly to the inflow of migrant labor.

Thus the critical areas of the rice production process in which some degree of mechanization needs to be introduced are transplanting and harvesting, in order to keep field operations on schedule and enable smooth implementation of double-cropping. It is in these two operations that the problem of mechanization is most acute, as very few advances have been made in even obtaining machines suited to in-field physical constraints characteristic of the major rice areas in Malaysia. Mechanization of land preparation is already well established and the present short-run problem here is fostering the use of the most economically efficient types of mechanical equipment.[13]

While labor shortage constitutes the primary justification for relatively extensive mechanization in the Scheme, the consequent rise in labor costs associated with labor shortage adds a further justification. Rising labor costs were already evident during the implementation of the first phase of double-cropping in 1970 involving about one third of the rice area in the Scheme. During the harvest of the first off-season crop in the Scheme, for instance, the cost of harvesting, threshing and primary transport is reported to have averaged about M$73 per acre[14] as compared to about M$53 per acre[15] for the same operations during single-cropping.

The Authority's support for mechanization of the critical operations of rice production identified above is therefore based, not on a blind acceptance of the ideology of technological innovation, but on basic economic and physical constraints associated with the introduction of rice double-cropping.

Economic Comparisons of Existing Forms of Mechanization and Associated Problems

This section of the paper reviews several aspects of forms of mechanization already being widely utilized in the Scheme or presently being field-tested. The role of economic research in this area is chiefly to determine the relative economic suitability of various different types of agricultural machines which otherwise satisfy technical performance criteria.

Comparative economic analysis has been undertaken wherever several different types of machines are found in any one operation. Research is also geared toward identifying potential economic problems associated with machine utilization, given the time constraints of double-cropping described earlier. Economic research of this nature contributes towards the formulation of mechanization policies.

A basic factor affecting the quality, and thereby the value, of economic research on mechanization is the research methodology itself. Realistic economic data on any agricultural machine can only be gathered from extensive field trials conducted under actual farm conditions. Field trials of this nature reveal actual in-the-field technical and machinery management problems, both of which affect machine productivity and the actual extent of operational costs. 'Stop-watch' type studies conducted within the closely controlled environment of research stations are necessary, but they do not form the only basis for the formulation of the Authority's mechanization policies.

The present status of rice mechanization in the Muda Irrigation Scheme is discussed below, and the main contributions of economic research are described.

Land preparation

Land preparation is the only operation in rice production in which mechanization has made significant progress in Malaysia. The beginnings of mechanization in this field are not associated with the introduction of double-cropping.

By 1960, a pattern of mechanization involving the utilization of two classes of tractors, pedestrian 2-wheel tractors and conventional 4-wheel tractors, had been established in the extensive single-crop rice area in the northwest of West Malaysia presently included in the Muda Irrigation Scheme. The adoption of mechanized means of land preparation in preference to the traditional buffalo-drawn plough appears to be related to the timeliness, quality of tillage and ease of mechanized land preparation, rather than cost.

The demand for mechanized land preparation has led to a rapid growth in the numbers of both 2-wheel and 4-wheel tractors, the latter being associated with the simultaneous development of a tractor contractor system. Increase in tractor numbers has, over the years, introduced a high degree of competitiveness into the tractor contract business, and mechanized land preparation rates have fallen greatly from the reported M$31 to M35 per acre in 1961[16] to an average of M$12.65 per acre at the present.

By 1966 approximately 40 percent of land preparation was mechanized,[17] and allowing for the growth of the tractor population since then, between 60 and 65 percent of land preparation in the Scheme is now estimated to be mechanized.

The bulk of mechanized land preparation in the Scheme today is undertaken by tractor contractors utilizing 4-wheel tractors currently running up to 77 horsepower. The ploughing implements in all cases are rotary-tillers of up to 70 inches in width.

The present number of contractor-operated 4-wheel tractors in the Scheme is estimated at 350 units. At least a thousand farmer-owned 2-wheel tractors are found, but the amount of contract work undertaken by these is insignificant, for reasons that the comparative economic analysis will later indicate.

In terms of the value of rice marketed by the typical farmer in the Scheme, tractors, whether 2-wheel or 4-wheel, are very expensive. The tractor contractor system has placed cheap mechanization within the grasp of every farmer.

The contractor system is based entirely on the utilization of 4-wheel tractors in conjunction with rotary tillers. The majority of these contractors appear to be not farmers but small-scale businessmen. The business is typically organized around a family unit, which generally owns only one tractor, although a tendency toward multiple ownership is now taking place.

The contractor system is highly competitive. Productivity is a major factor affecting choice of equipment. Over the years the trend in the contract business has been to purchase increasingly powerful tractors to enable the utilization of increasingly larger rotary tillers. The growth of the 4-wheel tractor population and the trend in brake-horsepower is shown in Table 3.

In spite of the availability of mechanized land preparation services from 4-wheel tractor contractors at rates averaging M$12.65 per acre (which incidentally are the lowest in Malaysia), there nevertheless has been a rapid increase in the number of farmer-owned 2-wheel tractors. In competition with 4-wheel tractors, however, the low productivity of these 2-wheel tractors has placed them in a comparatively disadvantageous position, and at prevailing cultivation rates of M$12.65 per acre, which are set by 4-wheel tractor contractors, 2-wheelers are unable to engage profitably in contract work. Chancellor,[18] in a study of tractor contractor operations, notes that owners of 2-wheel

Table 3. Growth of the 4-wheel Tractor Population and Trend of Average Brake-Horsepower in the Muda Irrigation Scheme 1960-March 1971.

Year	New Tractors Registered	Average Brake-Horsepower
1960	16	36.8
1961	41	39.9
1962	58	46.8
1963	57	50.8
1964	41	52.8
1965	29	54.7
1966	24	54.4
1967	36	56.1
1968	64	61.9
1969	83	65.9
1970	50	66.4
1971 (to March)	38	66.5

Source: Muda Agriculture Development Authority, *Conventional Agricultural Tractors in the Muda Irrigation Scheme: A Study of Tractor Population and Growth Patterns 1960–1971*, April 1971. (mimeograph)

tractors in Malaysia appear to be incurring average losses of M$150 annually.

There is further evidence in the Scheme to indicate the relative uneconomic position of 2-wheel tractors vis-a-vis 4-wheel tractors. The rate of repossession of 2-wheel tractors sold in the Scheme on hire-purchase is high. Further, realization of the low loan repayment capacity of these 2-wheel tractors, arising out of their inability to undertake contract work profitably, has driven the down payment required for hire-purchase from about 30 percent to a present maximum of 50 percent as a hedge against the greater risks now involved in financing these machines.[19]

While the Authority gives extensive support to rice mechanization, the basic criterion in the choice of equipment from among a number of alternatives must be the cost of mechanization to the farmer. There is no justification for small farmers to attempt individual ownership of initially cheap but uneconomic machines if alternatives exist for them to utilize more efficient, though initially more expensive, forms of mechanization.

This alternative already exists in the form of the tractor contractor system. This is further being supplemented by group-ownership of efficient equipment through the medium of farmers' organizations such as Farmers' Associations and Co-operatives.

Chancellor[20] states that the phenomenon of rapidly increasing sales of 2-wheel tractors in Malaysia in the face of the availability of cheap services from 4-wheel tractor contractors indicates that farmers place a certain value on personal ownership. Pride of ownership in this case, however, has a high cost. Unable to enter into contract operation on any significant scale, owners of 2-wheel tractors have to meet the cost of the tractor from other farm earnings. This is an unnecessary drain on farm incomes.

While the Authority is powerless to prevent the investment of private capital in what it regards as uneconomic forms of mechanization, it nevertheless can exercise considerable influence in the use of public sector funds provided for the mechanization programme in the Scheme. As a first step, group ownership of 4-wheel tractors through the medium of Farmers' Associations has already been initiated. Long term loans to Farmers' Associations at attractive rates of interest are provided for this purpose.

As a further measure to boost the adoption of 4-wheel tractors, the Authority has successfully appealed against the imposition of import tariffs on 4-wheel tractors and related agricultural implements.[21]

Comparative economic analysis of both 2-wheel and 4-wheel tractors, under conditions prevailing in the Scheme, is the basis for the Authority's preference for mechanization through 4-wheel tractors. Extensive field trials aimed at gathering realistic in-the-field production capacities and operational costs of 4-wheel tractors have been conducted in the Scheme under the constraints of actual farm conditions.[22] This is supplemented by various case studies of 2-wheel tractor utilization conducted in other rice areas of West Malaysia.

These types of economic research, supplemented by survey information, have enabled comparative economic analysis of two horse-power-range classes of tractors, namely 4-wheel tractors of the 60 and 70 brake-horsepower (b.h.p.) classes coupled to 60-inch and 70-inch rotary tillers, respectively, and 2-wheel tractors of 8 to 12 b.h.p.[23]

A summary of the significant findings of this comparative economic analysis follows.

The main basic for comparative economic analysis is the determination of realistic productivity levels for each type of tractor under the constraints of operation under actual farm conditions. The actual number of machine-hours taken to cultivate an acre cannot be used as a basis for determining daily productivity or production over a season of cultivation. In-field operational problems resulting in lost time, such as break-downs, location of farms, travelling time from farm to farm, etc., are always encountered in field operations and need to be taken into account. The study of 4-wheel tractors cited above revealed that in an average 10-hour working day, inclusive of down-time, a 60 b.h.p. class tractor coupled to a 60-inch rotary cultivator was capable of cultivating 5.7 acres. Under similar conditions a 70 b.h.p. class tractor with a 70-inch rotary cultivator produced 7.8 acres per day.[24]

Studies of 2-wheel tractors operating under similar conditions indicate that while machine hours per acre may be 4 to 5, the average daily productivity over a season of cultivation is less than 1 acre. A survey of 2-wheel tractors operated by farmer contractors in Province Wellesley, a double-crop rice area 60 miles south of the Scheme, showed that in an annual cultivation season of 2.7 months (81 days) the average level of output per 2-wheel tractor was 74 acres, or 0.91 acres per day.[25] Operator fatigue associated with 2-wheel tractors is so high that frequent stops are necessary. Further, 2-wheel tractors lack the mobility to travel over long distances for work opportunities.

With the productivity levels as identified above, an estimate of annual production for each class of tractor operating within the time constraints of double-cropping in the Muda Irrigation Scheme (six weeks per crop for land preparation or 12 weeks per year) can be made as follows:

1. 60 b.h.p. Class 4-wheel tractor—479 acres/year
2. 70 b.h.p. Class 4-wheel tractor—655 acres/year
3. 2-wheel tractor—84 acres/year

Using these annual production levels, the comparative analysis in Table 4 is derived.

Seen in relation to the prevailing cultivation price in the Scheme of M$12.65 per acre, the profit realized per acre at the stated level of output is M$1.57, M$4.41 and M$6.01 for 2-wheel tractors, 60 b.h.p. and 70 b.h.p. class 4-wheel tractors, respectively. It is doubtful, however, whether 2-wheel tractors in the Scheme even achieve break-even levels of output (whence the annual loss incurred by owners of these machines referred to by Chancellor). Because of low productivity, in spite of low purchase price, 2-wheel tractors are the least efficient users of labor and capital. Further analysis from Table 4 will indicate that outputs per dollar invested, at the stated output levels, are 0.16 acres for 2-wheel tractors, compared to 0.40 acres for the 70 b.h.p class tractors.

The foregoing analysis indicates the basis for the Authority's stand that promotion of the most economically efficient forms of rice mechanization combined with suitable forms of field organization will reduce the cost of mechanization to the individual small farmer.

Counter-arguments have been made that 2-wheel tractors are the only form of mechanization suitable for many soft-soil areas, which are found in some parts of the Scheme and of other rice areas in Malaysia.

The limitation imposed on the utilization of 4-wheel tractors by soft-soil conditions arises out of constraints inherent in the technical design of the tractor. This will be discussed in greater detail in the last section of this paper, which deals with what constitutes the ideal form of rice mechanization. The technical advantage which the 2-wheel tractor currently enjoys vis-a-vis the 4-wheel tractor in soft-soil areas does not come cheap, however. In Tangjong Karang, a soft, peaty-soil rice area on the coast of central West Malaysia, the *only* form of mechanization found is the 2-wheel tractor. The cultivation costs in this area, however, are as high as M$28 per acre.[26]

Table 4. Comparative Cost Analysis for 4-Wheel and 2-Wheel Tractors in Land Preparation in the Muda Irrigation Scheme.

(All Cost Figures in Malaysian Dollars)

	2-Wheel Tractor	60 b.h.p. Class Tractor + 60 Tiller	70 b.h.p. Class Tractor + 70 Tiller
1. Average initial cost (useful life)	3,100 (6 years)	15,580 (10 years)	16,400 (10 years)
2. *Annual fixed cost*			
(a) Depreciation (straight line)	517	1,558	1,640
(b) Tax & insurance	—	200	200
TOTAL	517	1,758	1,840
3. Annual production	84 acres	479 acres	655 acres
4. Average fixed cost (A)	6.15	3.67	2.81
5. *Average variable cost*			
(a) Fuel	1.68	1.33	1.33
(b) Oil & grease	0.25	0.46	0.46
(c) Repairs & parts	3.00	2.78	2.04
TOTAL (B)	4.93	4.57	3.83
Total cost per acre (A + B)	11.08	8.24	6.64

Source: Muda Agriculture Development Authority, *A Comparative Economic Analysis of Conventional and Pedestrian Tractors in Rotary Cultivation,* Aug. 1970.

Note: Labor cost was excluded from calculations in Table 4 because comparable wage rates are so difficult to establish where labor productivity varies so greatly according to type of tractor. The difference between cultivation price and cost per acre may, however, be regarded jointly as return to labor and management.

Transplanting

Transplanting at present is a completely manual operation in Malaysia, and, as indicated earlier, needs to be mechanized to some extent to permit the Scheme to follow double-cropping schedules. Already in the first phase of double-cropping, labor shortages for transplanting were apparent which led to many areas being behind schedule. Mechanization of at least a portion of transplanting has become a matter of critical importance.

Two-row pedestrian-operated mechanical transplanters have been tried in several parts of the country but all have failed, owing mainly to poor water control and to uneven soil-conditions, which the soil-levelling plates on these small, light-weight machines were unable to remedy. Undoubtedly redesign of these machines could potentially make them workable, but, as with the case of the 2-wheel tractor, low productivity and high operational cost are likely to be associated problems. The cost of this form of mechanized transplanting will not be cheap.

Mindful of the findings of the comparative economic analysis of land preparation equipment, the Authority, with Japanese technical assistance, is currently engaged in the development of an 8-row mechanical transplanting *attachment* to be used with an external power source such as a 4-wheel tractor. When technical problems associated with the design of such an attachment to suit Malaysian rice soil and water conditions are solved, ready application can be expected through the medium of the tractor contractor system and/or group ownership schemes.

Harvesting

Harvesting, the most labor-intensive operation in rice production, is currently also the most expensive for the farmer. With increasingly larger acreages being brought under double-cropping in the Scheme, severe labor shortages are being experienced, resulting in rising labor costs and delayed harvesting.

It is in this operation that introduction of some amount of mechanization is most urgent.

The relatively high cost of manual harvesting, even during single-cropping, has acted as an incentive for local agricultural equipment distributors to attempt the introduction of small self-propelled pedestrian-controlled rice combines, powered reaper-binders, power threshers, etc. None of these, however, have found acceptance in any part of Malaysia. Again the problem appears to be related to the low productivity of these forms of mechanization, the fact that no great reduction in labor requirement is effected, and in some cases to their unsuitability to physical conditions in the major Malaysian rice areas.

Other forms of mechanization in harvesting, such as power threshers, have been tried but have met with little or no farmer acceptance, as they do not significantly reduce labor requirement. Power threshers, for instance, save some physical effort in threshing, but the same amount of labor is still required for reaping and carrying of rice sheaves to the thresher.

The Authority's short-term plans to mechanize rice harvesting centre around the introduction of large-scale combine harvesters. At the present time six 7-ton 13-foot-cut combine harvesters of European manufacture, suitably modified for rice harvesting under soft, flooded soil conditions, are being used to provide mechanized harvesting services to farmers on a contract basis. Economic studies undertaken during contract harvesting operations with these large combine-harvesters[27] have demonstrated convincingly the advantages of large-scale farm machinery and the contractor or group-ownership form of organization in bringing efficient and cheap mechanization within the grasp of the small farmer.

The productivity of large-scale combine-harvesters is particularly impressive. In economic studies on combine-harvesting conducted during contract-harvesting operations in farmers' fields in the Scheme in a wet-season harvest under flooded soil conditions, the combines averaged 1.12 hours/acre; in a dry season, which enabled the use of rubber tyres instead of tracks, the combines averaged 0.54 hours/acre. This included reaping, threshing, grain-straw separation and disgorging of clean grain onto bagging hoppers or platforms. The best daily output recorded in the studies was 11.9 acres in a 10-hour working day.

Small plot sizes, though lowering combine productivity, were never found to be a serious problem, the relationship between harvesting time and plot size becoming negligible once plot size of 1.5 acres had been reached. Variable costs averaged M$10.82 per acre.

In spite of high productivity and low operational cost per acre, certain limitations exist in the economic utilization of combine-harvesters as large as these in the major rice areas of Malaysia. Because of size, physical problems of accessibility to rice fields and soft soil areas limit their utilization. Further, as access from farm to farm is generally over rice fields, lack of perfect uniformity in harvesting schedules between farms in any one area results in unproductive time while suitable alternative access routes are located. Owing to the high initial cost of large combine-harvesters, unproductive time for any reason becomes very expensive, as average fixed costs increase with lower utilization.

A high degree of field organization and in-field management is critical if the high productivity of these large combines is to be utilized profitably. These factors have been responsible for the non-acceptance of large combines by private contracting businesses.

It appears, however, that a substantial market exists for a smaller and cheaper rice combine of around 4 tons, ground pressure of less than 5 lbs. per square inch, and equipped with a 7 or 8 foot cutter-bar. This has aroused considerable interest among major agricultural equipment distributors in the country and some smaller combines are currently being brought in for field trials.

Problem of under-utilization of specialized large machinery

The general economic justification is clear for the mechanization of rice cultivation in the Scheme through the utilization of the more productive large machines in preference to individual-farmer ownership of small machines.

The small size of the average farm is in itself not a constraint in bringing efficient forms of mechanization to the farmer. The tractor-contractor system of organization described earlier has proved highly successful in this respect. The high degree of competition characteristic of the tractor-contractor business has resulted in very low prices for mechanized services to the farmer and has further been instrumental in bringing about a continuous inflow of the latest and most productive equipment.

Mechanization through the introduction of large machinery, however, is not without its own economic problems. The major one, arising out of the imposition of stringent double-cropping schedules, is under-utilization. With double-cropping, although a demand for more mechanization is created owing to the scheduling of cultural operations, the highly seasonal nature of demand itself restricts the utilization of machinery to relatively brief portions of the year.

The high productivity and efficiency of large farm machinery is unfortunately also associated with high fixed cost. High levels of output are therefore essential if investment is to be profitable and cost of mechanization to the farmer is to be low.

Given the time constraints of rice double-cropping in the Scheme, tractors used in land preparation would be idle 9 months of the year. (Chancellor, in 1968, reported that tractors were idle 7 or 8 months of the year.[28])

Despite the stringent schedules required for double-cropping, however, tractor contractors do achieve levels of output sufficient to enable substantial profits at relatively low prices. Typical annual profits of M$4110 for 4-wheel tractor contractors in Malaysia are reported.[29] This, however, is only made possible by extremely intensive utilization during the peak periods of demand, in which non-stop operation with a relay of operators is common.

The fact remains that tractors are idle for the major part of the year. As average fixed costs decrease with greater output, it is clear that greater utilization will ultimately be a factor that can help reduce mechanization cost to farmers.

The opportunities for significantly greater utilization for 4-wheel tractors in Malaysia are small outside of rice cultivation. Only 14 percent of the total area of annual crops in West Malaysia is under crops other than rice, and these are mainly small, scattered areas. Some demand probably exists in land clearing for tree crops, but this again is uncertain and sporadic. The problem of under-utilization for major portions of the year is likely to be greater with more specialized and single-purpose machines such as transplanters and combine harvesters.

The Ideal Form of Rice Mechanization: the All-Terrain, Multi-Purpose Prime Mover

Determination of what constitutes the ideal form of rice mechanization involves a brief re-statement of the earlier discussions on the technical and economic problems associated with the utilization of conventional forms of large farm machinery.

Technically, these forms of machinery, though highly productive and efficient, lack universal adaptability to the diverse soil and field conditions of major rice areas. Although substantial rice areas do exist which are capable of effectively utilizing conventional farm machinery, there nevertheless also exist considerable areas of rice where problems of soft soils and accessibility limit their use, yet where the need for mechanization is no less acute.

Economically, the problems associated with the use of highly specialized and relatively expensive farm machinery, especially with respect to the time constraints of double-cropping, relate to the possibility of under-utilization resulting in high cost per unit of output.

The ideal form of mechanization for rice must overcome both these problems. It must have a high degree of adaptability to soft and difficult soils, which present problems of sinkage and traction to any conventional agricultural machine; it must be capable of significantly higher annual levels of utilization under the time constraints of rice double-cropping, than any machine presently utilized. And third, it must be capable of adequate levels of productivity.

Rather than concentrating on the adaptation of available forms of mechanization to the varied soil and environmental conditions of rice areas and pressing for maximum utilization during the brief periods of intense demand, a viable technical and economic solution might exist in *the development of a multi-purpose prime mover based on the all-terrain-vehicle concept, designed to suit the diverse physical environment of rice areas, and intended to act as the source of locomotive and operative* *power for a variety of single-purpose agricultural implements.*[30]

It is emphasized at this point that while the Authority is conducting work on the adaptation of large farm machinery to suit Malaysian rice conditions, the concept of the all-terrain multi-purpose machine is under simultaneous investigation. Actual developments have proceeded beyond the conceptual stage.

Several all-terrain prototypes, built with the technical co-operation of private corporations, are now in the process of being field-tested by the Authority. The functional implements required for the mechanization of the critical operations of rice production, namely tillage, transplanting and harvesting, already exist or are in the process of development. Standard rotary-tillers, proven in rice field use in Malaysia, are readily available. An eight-row transplanting implement of Japanese design is currently being modified for local soil and water conditions. A medium sized harvesting attachment is being developed. The concept of the multi-purpose machine further incorporates an in-field transportation capability.

The technical and economic justification for this approach are clear. First, implicit in the all-terrain-vehicle concept is its adaptability to a wide range of soil conditions and accessibility limitations which pose problems for any agricultural machine presently utilized.[31] The design of any vehicular system for rice mechanization must of necessity incorporate a high level of mobility and manoeuvrability under the wet, sticky soil conditions in rice fields. A high level of flotation and soft-soil trafficability is essential to prevent bogging (sinkage) in deep soft soils. Accessibility constraints such as inadequate roads and small bridges exist in the major rice areas. By definition, therefore, the all-terrain-vehicle, modified to facilitate utilization of standard agricultural implements, [32] appears as the obvious solution to the physical and technical problems of rice mechanization.

Second, the concept of the all-terrain-vehicle as a *multi-purpose* prime mover for a variety of functional implements should enable utilization for significantly greater periods of time per season than is possible for conventional single-purpose machines performing only one operation. High levels of utilization of the prime mover result from its ability to perform several of the operations of rice production. High utilization results in low fixed cost per unit of output. This constitutes the primary economic justification for such an approach toward rice mechanization.

The basis for comparative economic analysis with alternative forms of mechanization (conventional single-purpose machines) must be with reference to relative levels of productivity and cost. Productivity is partly a function of power capacity of the prime mover and partly of the implement size. A brake-horsepower capacity of between 50 and 60 b.h.p. is envisaged for the prime mover. This is considered sufficient to enable the utilization of rotary-tillers of 60 to 70 inches at levels of productivity comparable to conventional 4-wheel tractors.

Since tillage generally requires more power than any other function, this power capacity is sufficient for the transplanting and harvesting attachments and transport payload capacity envisaged.[33]

As the ultimate justification for the multi-purpose machine concept is the minimization of total cost per unit of output, major factors to be considered are fixed costs (acquisition cost of the prime mover) and average variable costs. An acquisition cost for the prime mover comparable to a conventional tractor is envisaged, but as higher levels of utilization are implicit in the multi-purpose concept, a somewhat higher acquisition cost is justified. Variable costs per unit of output in the performance of different functions will be close to those of single-purpose machines of comparable performance.

Given the above relative productivity and cost assumptions, the outcome of comparative economic analysis is obvious. The prime advantage possessed by this concept of mechanization is maximum utilization. By performing several of the critical operations of rice production, the fixed costs of the prime mover are spread over a greater number of output units, thereby lowering the cost per unit of output significantly below that of conventional single-purpose machines capable of performing only one operation.

Theoretically, a multi-purpose prime mover would be a viable proposition even if it performed only two functions at productivity levels comparable to single-purpose machines. It is apparent that, apart from the role envisaged for the all-terrain-vehicle in tillage, transplanting, harvesting and in-field transport, an even greater level of utilization can be achieved by performing other functions, such as pumping, spraying, etc., which are presently associated with the conventional tractor. It is further apparent that, although ideally productivity levels in the performance of individual operations should be at least equal to those of special-purpose machines, the maximum utilization advantage of the multi-purpose machine will allow somewhat lower levels of productivity and yet be capable of lower costs per unit of output.

The all-terrain multi-purpose prime mover is thus seen as a viable solution to the technical and economic problems associated with the introduction of productive and efficient forms of mechanization to rice production in Malaysia. To provide a market of sufficient size to warrant the development of such a machine, widespread applicability to the major rice areas of Southeast Asia, where conditions are somewhat similar, can be expected.

From the perspective of the development planner, the fundamental appeal of this concept toward rice mechanization, relative to alternative forms, lies in its inherent capacity to provide mechanization at the lowest cost to the farmer. By lowering on-farm production costs this can increase net farm incomes, which, in the final analysis, constitutes a basic economic justification for farm mechanization.

[1] *Statistical Digest of West Malaysia 1969*, Ministry of Agriculture and Lands, Kuala Lumpur, March 1971, Table B 1.

[2] Udhis Narksawasdi, *A Report to the Government of Malaysia on the Rice Economy of West Malaysia*, Food and Agriculture Organization of the United Nations, Rome, Jan. 1968.

[3] *Statistical Digest of West Malaysia 1969, op. cit.* Table B 14.

[4] A discussion and analysis of these physical and economic constraints is presented later in the paper.

[5] Some idea of the relative importance of the Scheme as *the* major rice area in Malaysia may be obtained from the fact that the next largest double-cropping project, the Kemubu Scheme, covers only 47,000 acres, i.e. is less than one-fifth as large.

[6] *Farm Economic Survey of the Muda River Project, 1966.* Ministry of Agriculture and Cooperatives, West Malaysia, Kuala Lumpur, Sept. 1967, Table 22.

[7] *Farm Economic Survey of the Muda River Project, 1966, op. cit.*

[8] *Farm Economic Survey of the Muda River Project, 1966, op. cit.* Table 15.

[9] Khairi bin Hj. Mohamed and Mohamed Tamin bin Yeop, *Socio-Economic Survey and Its Implication to the Muda Irrigation Project.* Info. Paper No. 5, Div. of Agriculture, Ministry of Agriculture and Cooperatives, West Malaysia, (mimeograph).

[10] Khairi bin Hj. Mohamed, *Agricultural Labor and Padi Varieties: Two Related Problems in the Muda Irrigation Scheme*, Dept. of Agriculture, Kedah, Oct. 1968, (mimeograph) p. 8.

[11] Source: Department of Immigration, Alor Star, Kedah.

[12] Dams constructed as part of the engineering infrastructure of the Scheme supply only one third of annual irrigation water requirements for double-cropping. One crop has to depend largely on direct rainfall during the rainy season. The present double-cropping schedule is therefore designed to enable maximum utilization of the limited quantity of impounded water.

[13] This is discussed in detail in the following pages.

[14] Muda Agriculture Development Authority, "The Cost of Padi Production in the Muda Project Area," June 1971 (unpublished).

[15] Dept. of Agriculture, Kedah, "Cost of Padi Production, 1968" (unpublished mimeograph).

[16] The 1961 Annual Report of the Kedah State Agricultural Officer makes the following observation:

"This year (1961) approximately 13,831 acres of rice land was tractor ploughed... In North Kedah, the cost of tractor ploughing varies from between \$22–\$25 a *relong* (approximately \$31–\$35 per acre)... The cost of ploughing with buffalo is roughly the same but takes several weeks whereas the tractor completes the job in 1 *relong* (0.711 acre) in 2–3 hours..." Dept. of Agriculture, Kedah, *Annual Report for 1961*, p. 6 (Translated from Malay).

[17] *Farm Economic Survey of the Muda River Project, 1966, op. cit.*, Table 20.

[18] Chancellor, W.J., *Survey of Tractor Contractor Operations in Thailand and Malaysia.* Agr. Engineering Dept., Univ. of California, Davis, Calif. (Aug. 1970) p. 9.

[19] Private communication with farm equipment dealer in Alor Star, Kedah.

[20] Chancellor, *op. cit.*, p. 11.

[21] Tariff protection was originally granted to local assemblers of 2-wheel tractors. The tariff, however, was not discriminating, and all imported agricultural machinery for land preparation became subject to it. Subsequent to the Authority's publication of a paper on the possible adverse effects of this to the Nation's mechanization programme, this tariff was removed. See Muda Agriculture Development Authority, *Import Tariffs on Agricultural Inputs and Its Implications on Rice Production*, Nov. 1970 (mimeograph).

[22] Muda Agriculture Development Authority, *Conventional Tractors With Rotary Cultivators: An Economic Report*, Aug. 1970.

[23] Muda Agriculture Development Authority, *A Comparative Economic Analysis of Conventional and Pedestrian Tractors in Rotary Cultivation*, Aug. 1970.

[24] The productivity of 4-wheel-tractor contractors in the Scheme is generally much higher, as they are not restricted to a 10-hour working day.

[25] Len, S.C., and Abdul Mutalib bin Ahmad, *Utilization Study of Farm Machines in Padi Production*. Rice Research Centre, Province Wellesley, Malaysia, June 1968.

[26] Udhis Narksawasdi and S. Selvadurai, *Economic Survey of Padi Production in West Malaysia*. Report No. 1—Selangor, Ministry of Agriculture and Cooperatives, West Malaysia, Kuala Lumpur, Jan. 1967, p. 75.

[27] See Muda Agriculture Development Authority, *An Economic Report on Combine Harvesting of Padi in the Muda Irrigation Scheme*, Dec. 1970 (mimeograph).

[28] Chancellor, W.J., *op. cit.*, p. 14.

[29] *Ibid.*, p. 9.

[30] Muda Agriculture Development Authority, *The All-Terrain Vehicle—Its Potential As a Multi-purpose Prime-Mover in Rice Production*, July 1971. This publication is an intensive study into the technical and economic justification for such an approach toward rice mechanization.

[31] Even the 4-wheel tractor, used so extensively in tillage in firmer rice areas, has found acceptance only by adaptation to the conditions of rice soils, partly by the use of wheel-extensions and partly by the widespread use of the rotary-tiller, which itself imparts a forward thrust to the tractor.

[32] These modifications include S.A.E. standard P.T.O. shaft at 540 and 1,000 R.P.M., independent PTO clutch, a standard Category I 3-point hitch, double acting hydraulics front and rear, with a lift capacity comparable to conventional tractors.

[33] It is probable, however, that levels of productivity at any given power capacity and implement size may be greater with the all-terrain prime mover than with conventional machines, as with the latter significant power is required for traction alone.

AGRICULTURAL MECHANIZATION OF ASIAN COUNTRIES

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For more than 50 years, Japanese manufacturers of agricultural machinery have been engaged in the mechanization of farming in Japan. In both past and present the central problem that has confronted them is the fundamental role of agricultural machinery and the farmers' motive for purchasing machinery.

Prior to the present stage of agricultural mechanization in Japan, there was a long intermediate period between the early stage of the 1850s and the rapid changes that began in the 1950s. This intermediate period saw a wide diffusion of manual and animal drawn implements such as improved plows, foot-pedal threshers, revolving weeders and irrigation pumps. From the middle of the 1950s power machinery made a rapid spread, with the power tiller playing a main role.

Judging from the course of the past and in light of the indispensability of technical renovation surrounding the farm industry, it is obvious that the economic standard of a nation has changed the characteristics of necessity for agricultural machinery. In other words, technical renovation which made it possible to develop the hardware, i.e. agricultural machinery, and the purchasing capacity of farmers based on various factors coincidentally created the necessity of agricultural machinery and the technology of agricultural mechanization.

Agricultural mechanization in Japan is now in process of a shift from power tiller to 4 wheeled tractor. Considering the capital investment that would have been required for land consolidation, the economic standard of Japan in the middle 1950s did not permit an immediate switch from manual and animal farming to tractor farming at that time.

On the other hand, the environment of farming is constantly changing from the period of surplus farming labor desperately trying to lift up food production, to the stage of producing low-cost farm products with a steady decline in the farm labor supply. Furthermore, more farm operators are beginning to treat farming as a side job, and there are also increasing signs of concern about ways of farming that preserve the natural environment.

Thus, the object and the suitability of agricultural machinery are more and more changing scope and character.

When we consider international circumstances surrounding other Asian countries and their economic standard, it appears that agricultural mechanization in many of these countries has just moved into an intermediate stage.

Accordingly, the goals of agricultural mechanization should be, first of all, to promote proper timing of farm operations, intensive farming by multi-cropping and/or intercropping, diversified farming, increased income through knowledge of farm management and farm economics, and at the same time, contributions to higher food production by higher land productivity.

These endeavors should also raise farmers' incomes and living standards.

Until recently, policies for increasing food production in Asia relied mainly on the expansion of arable land; not on scale expansion for existing farmers but on expansion of newly established farmers. Now it must be recognised that the time for putting expectation on arable land expansion has already gone.

The problem of elevating labour productivity, another main necessity in mechanizing agriculture, has not yet been accepted as an urgent matter in Asian countries holding surplus farming labour, though in many places there is evidence of labor scarcity during the busy harvest season.

Necessary Conditions for Introducing Farm Machinery

Four broad classes of conditions relate to farm mechanization, (1) labor, (2) standard of income, (3) basis of farm land and (4) primary social factors. However, in Asian countries these conditions are influenced by as well as influencing progress in agricultural mechanization.

Labor supply

In most Asian countries 50 to 90 per cent of the total working population is engaging in farming. Asian countries possess a greater supply of good quality farm labor than any other part of the world. To leave these workers unemployed or semi-unemployed means a great loss to the nation concerned, not only from the viewpoint of her economy but also from a social standpoint.

The fact that so many Asian countries have set up an intermediate economic development plan and are paying utmost effort to its achievement is to be admired. These plans vary in agricultural emphasis and industrial emphasis. Generally speaking, however, plans which develop industry and mining to absorb surplus labor, elevate national profit, and improve international income and foreign exchange accounts are quite sound because, as the history of developed countries has shown, absorption of surplus farm labor or potential unemployed by industry, and establishment of a products interchange system between urban and rural sectors, is the object and process of modernization.

By the way, criticism is often heard about the heaped up wrecks of highly efficient tractors which had been imported by Asian countries but not effectively used because of misselection of implements and insufficient supply of spare parts. The fundamental reason for such miserable results is probably that the environment was not ready to receive these tractors.

Standard of income

In most Asian countries, due to surplus labor power and limited industrial development, wage rates for labor are roughly a third of those in Japan. This low income standard leads to low productivity and becomes part of a vicious circle mechanism of low productivity and stagnation.

To conquer the low income syndrome requires overcoming many problems which can only be solved by steady and long range schemes such as, for instance, effective land reform, promotion of investment for higher productivity, and establishment of farm product processing factories which give wide and effective employment opportunities from money invested.

Because of low income standard, machinery purchasing capacity is low. In addition, there are insufficient financing facilities for machinery purchasing and most farmers can not afford machinery from their own cash resources. Because of such circumstances, demand for machinery is not sufficiently responsive to questions of the efficiency with which it can be used.

Basis of farm land (diffusion)

As the result of the long colonial period in the countries in South and Southeast Asia, there still exists the dual structure of agriculture, i.e., large plantations and subsistence farmers. Often the latter have dropped down to peasant and/or farming laborer status. The land of such a family-scale farmer is further split into smaller pieces by the inheritance system. Therefore, providing farm roads, integral development, and betterment of such necessities as drainage are indispensable. In such a situation, land reform should be done prior to the introduction of agricultural machinery.

Agricultural machinery can also contribute to breaking from the mono-culture farming which has been an economic characteristic of Asian countries.

Primary social factors (education and enlightenment)

Traditional elements of the social structure such as low education level, closure system of farming society, and exploitation by money lenders cannot be disregarded as factors which keep agriculture in Asian countries inactive and prevent progress of agricultural mechanization.

Economic cooperation

Asian countries are looking for capital and technical cooperation from Japan. Especially they are expressing keen interest and expectation of economic cooperation to the extent of one per cent of Japan's GNP. Economic cooperation of Japan with Asian countries in the past has to some extent lacked positiveness. To respond to the expectations of Asian countries, Japan must develop newer measures that demonstrate confidence in economic cooperation, especially with Asian countries that have displayed energetic willingness to work toward this end.

It is gratifying to note that administrators in Japanese government are beginning to recognize the importance of agricultural development. Along with the self-supporting efforts of developing nations, it is urgently necessary for the more developed countries to extend cooperation.

Alleviation of direct credit shortages, wider scope for technical cooperation, assistance from Import-Export Bank and various funds to private investment, more effective enrichment of the insurance system, and favorable taxation measures toward private investment are strongly desired.

In many Asian countries the good results of economic development in the 1960s generated considerable hasty economic nationalism. One would list these as some of the objectives of economic nationalism: specified percentages of share holding in joint-venture company, development of home production of machinery parts, employment of local staff in management, training of technicians and workers, responsibility of re-exporting.

Although it is impossible, in some cases, to satisfy all of these desires, it is natural to make an effort to harmonize with nationalism on the basis of mutual confidence through consultation with governments and potential partners in other countries.

In general, the role of foreign capital is important in Asian countries. Accordingly, it is presumed that foreign capital will continue to become more and more important to cover gaps of investment deposit, trade income, outgoing accounts, and technology.

Introduction of foreign capital hereafter needs enlarged direct investment, increased acceptance of government credit, and longer term private credit. On the part of accepting countries, at the same time, it is necessary to establish appropriate policies for working with creditor countries.

Although in the field of technical cooperation, lack of qualified experts to work overseas is one of the problems, Japanese manufacturers of agricultural machinery are ready to make more effort directly and indirectly.

As a particular case of technical cooperation, members of the Japan Overseas Corporation Volunteers dispatched abroad have been carrying with them agricultural machinery to introduce. More expansion, introduction and technical cooperation of this sort is highly desired. In the field of economic cooperation, the necessity of capital aid to organizations financing agricultural activities in developing countries is also important.

Role of Japanese Agricultural Machinery Manufacturers

International Division of Work

Exports of Japanese-made agricultural machines now average around 50 million dollars a year, but this is less than 7 percent of total production. It is far lower than export levels for other developed agricultural machinery manufacturing countries.

Although the Japanese export market spreads all over the world, 50 to 60 per cent of it is occupied by the Asian countries. Of course, this is because of geographical advantage. Another factor, however, is that in Asian countries wet field rice is the main crop, and its scale is closely related to that of Japan. Therefore, the applicability of Japanese-made machinery to these countries is one of the most important factors. At the same time, Japanese agricultural machinery performs a part of the Governmental aid program toward agricultural development in the Asian region.

For a point of reference, if the world market for agricultural machinery were at the level of present-day mechanization in Japan, the market in other countries for rice farming machinery would be about 40 times what it is in Japan. Of this, 90 per cent is concentrated in the Asian region.

On the other hand, overseas-made machinery imported into Japan now has a value equivalent to Japan's exports. This clearly shows that the influence of international division of work is rapidly surging upon Japan. When we consider the world market of agricultural machinery and the agricultural machinery industry, the necessity of international division of work is becoming more and more important. Japan's approach to Asian countries should also be considered from the standpoint of international division of work.

Its approach to them from standpoint of machinery prices should be vis-a-vis the price of agricultural products. Furthermore, it has close relation with the industrial standard of a nation. Accordingly, it is difficult to compare prices of agricultural machinery internationally. Therefore, it is better for a country to start domestic manufacture of agricultural machinery which will counterbalance with her industrial standard.

Overseas investment attitude of Japanese manufacturers

Overseas investment of Japanese agricultural machinery manufacturers counts 9 enterprises at present, and total investment as of December 1970 amounts to approximately 5.28 million dollars only. Of this, 85 per cent is security acquisition and 15 per cent is bond acquisition. Areal classification shows 6 out of 9 in the Asian region and the balance in Central and South America.

Power tiller occupies the largest share, then thresher, and third sprayer.

Investment in Central and South America started from 1957, while in the Asian region it started from 1960. Status of investment shows 100 per cent from the Japanese side in Central and South America, but in the Asian countries less than 50 per cent of each project.

Sales amount of 7 out of the 9 overseas enterprises totaled about $10 million in 1970. Re-export to third countries was only $700,000. It might be expected that re-export to Japan will take place in the future.

Regarding the cost of products, using an index for manufacture in Japan of 100, elsewhere in the Asian region it is 120–200 and in Central and South America 180–300, showing considerably higher cost. Higher cost in these countries is caused by the fact that because of insufficient industrial development they cannot order the required components from sub-contractors (in Japan these components will naturally be ordered out). They are forced to manufacture components in their own works or depend on imports. In addition, manufacture of components locally in small quantity gives no benefit of mass production.

Regarding business results of these investments, 3 out of 7 are running with red ink. Even for the other four the profit percentage is as low as 3 to 4 per cent.

In the case of sprayers, competition exists between Japanese makers and European and American ones. In the field of power tillers competition exists only among Japanese manufacturers.

In the assembling of knock-down components under technical collaboration, there are 18 projects at present. Power tiller projects overwhelmingly occupy 13 out of the total. Area classification shows 15 projects out of 18 located in the Asian region.

The motive for entering an overseas market in some cases is the encouragement of the government of the country. The majority of them start such collaborative projects along with import prohibitions to protect markets opened by the export of goods at earlier stages.

Due to serious concern about recovery of invested capital, investors are keen for short period recovery and therefore do not like to contribute to the real development of the agricultural machinery industry of competing countries. In this connection it would be useful to have some kind of guarantee or protection policy by the government.

According to investigation made by MITI, the value of Japan's export of agricultural machinery in 1980 is predicted to be $325 million, occupying 23 per cent of total production. Export percentage of completed goods to Asian countries is predicted to drop sharply and local manufacture to have a sizeable increase.

Overseas investment in 1980 is estimated about $3,000 million, or approximately 6 times that of 1970, mostly for securing and opening new markets. One of the problems to Japanese concerned is that because of keen investing competition among manufacturers they are intentionally accepting rather disadvantageous conditions in order to maintain dependable management. Also, because of limited effective demand at present stage, full scale of local manufacture is not yet realised. However, it is presumed that more expansion will materialise in the near future.

During the course of the 1970s many Asian countries will face a new turn in economic policy because of rapid change in industrialization and the international environment. The key points of economic policy may be different in different countries. They, however, are materializing in the direction of forming newer economic development plans based on self-supporting effort and international cooperation in the face of ever-changing international affairs.

Many Asian countries have corrected their direction from a policy of promoting import substitution industry to a policy of strengthening export industry. This will considerably influence the development of the agricultural machinery industry.

Generally speaking, industrialization in the 1960s had as it principal object lifting protective tariff and import restrictions in order to save foreign exchange and promoting import substitution industries to absorb unemployment. It is clear that the result of this policy, due to limited demand, was small scale industry with high production costs. Yet, increased import of capital goods and raw materials invited more outflow of foreign exchange affecting badly the agricultural machinery industry.

There is an extreme argument that the difference between developed countries and developing ones does not rest in economic development but in population increase. And this tendency may often force a policy inclining to one specific industry. This is a by-product of temporary compromise in the course of changing old agricultural-minded societies to industrial ones. Therefore, it might be natural that once economic modernization is put into effect, the policy will immediately be switched over to a system putting weight on industry.

From the view point of industrial development in Asian countries, keen attention is paid to progress in home production of agricultural machinery. This matter is taken up as an important subject by the Asian Conference of Industrialization jointly sponsored by ECAFE and UNIDO.

Anyway, it is quite clear that more and more demands will be put on Japan's capital and technical cooperation. All Japanese manufacturers of agricultural machinery are ready to offer their service to cope with the enthusiasm and great expectation of the leaders of these countries, looking closely at the problems of each country to overcome difficulties in promotion of an agricultural machinery industry. And, we as manufacturers expect that government will lend appropriate cooperation in this line.

Asia, which largely consists of nations growing primary products, is affected by chronic sluggishness of its overseas markets. Therefore, it is indispensable for Asian countries to strengthen industry other than primary products, especially industrial production.

Generally there is no obvious alternative to "growth by exporting agriculture". As Thailand knows, however, when export is limited only to primary products it invites many dangers. Such export economics will one-sidedly be influenced by unexpected change in the overseas market. At the same time, there is always price instability of exporting products. On this point, consideration of developed countries importing such products is requested. It is, however, necessary to develop complementary industry based on primary products.

Not simply in the Asian countries, but in all other developing countries, it was after World War II that industrial development plans were launched and vigorous efforts begun to achieve them.

Coming into the 1970s, industrial development came to have equal importance with agricultural development for the purpose of accomplishing economic growth and employment. And eventually with its urgency and importance it was included in international development schemes.

The 1960s were designated as "The First United Nations Development Decade" aimed at the economic advancement of the developing countries. But this period ended as a "Decade of Frustration" inviting insincerity and a great disillusioned feeling.

In order to break this deadlock a "Second U.N. Development Decade" was launched and saw the GNP of these developing countries lifted up by 6 per cent. And it has become a guide wheel of accelerated economic growth, bearing heavy responsibility for success or failure of progressing industrial development.

In these days, "property" in an economic meaning is not machinery itself but its design. Furthermore, it is rather the endeavor to pay attention to change in production procedure and design of products.

Asian countries are inclined to admire symbol rather than efficiency and this has tempted them, for example, to insist on producing a completed power tiller rather than making only the frame. It is believed that such characteristic often raised problems of copying products of others.

It is fully imaginable that for the time being nations in the world may take retrogressive attitudes against protective and exclusive policies. And Asian countries may take policies to nationalize existing foreign enterprises or strictly control their incomes, and on the other hand enforce any possible law or regulation to accelerate home production.

We, however, presume that in the 1970s many countries in Asia will probably realise mechanized and large scale production or labor-eliminated intensive production, and bring the per unit labor cost close to the level of industrialized countries.

In an investigation made by APO recently, the following factors were noted as restricting agricultural mechanization in Asian countries:

1. Lack of technics required for manufacturing machinery;
2. Scarcity of capital for plant establishment, and consequently lack of suitable factory buildings;
3. Shortage of spare parts (partially caused by import restrictions and high tariff rates); and
4. Lack of places and institutes required for training people.

An analysis of these problems shows a number of measures that are urgently needed.

Financing measures

Needless to say, economic development or industrialization takes enormous amounts of capital. For a developing nation whose internal capital is insufficient, it is natural to seek capital aid from abroad. Especially for agricultural development, medium and long term finance is indispensable. Along with private investment, direct investment of special social capital by the government is indispensable for the development of agriculture. Judging from scarcity of financial capacity at the present stage, it is strongly desired to strengthen their capital, including bank loans.

Concert of financial aid funds from developed countries is required. In Japan, concert relation between internal aid funds (Overseas Economic Development Cooperative Fund, K.R.

Food Staff Aid, and gratuitous capital) and international funds (Special Agricultural Fund of Asian Development Bank, and Special Technical Cooperation Fund) is necessary.

Along with coordination of fund aid measures by developed countries, systematic planning by countries receiving these funds is also essential (for example, re-arrangement of financing organization in Indonesia and Burma, replenishment of central bank in Thailand and Malaysia, etc.). It is noteworthy to observe the establishment of development banks in these countries and the serious effort being devoted to the betterment and progress of agriculture.

Present price support policy has become a main factor in rising consumer prices and wage inflation. Therefore, farmers' income betterment policy has certain limits. As in Japan, measures putting rice under direct control and setting higher production against lower consumer price may stop inflation to some extent. However, this measure forces government to bear tremendous amounts of financing.

To solve income difference and at the same time provide consumer price control, it is necessary to set up a well planned public financing policy.

In the developed countries in these days, agricultural financing organizations have recently begun to finance projects other than farm management narrowly defined. This kind of financing contributes to the united progress of agriculture and related industry. This tendency involves expanding from agricultural promotion to projects of processing agricultural products and even to the commodity circulation structure. It is desirable, furthermore, that not only organizationally specialised agricultural credit bodies but also non-agricultural credit bodies operate in the field of agriculture, because this will provide additional finance to agriculture and furthermore will stimulate sound competition in credit markets.

Financing standards should move away from rigid dependence on property mortgages offered by farmers. It is better to set up new standards based on consideration of the farmer's management ability and market situation.

When we classify broadly the existing financing bodies, there are two kinds. Organized financers include commercial banks, agricultural cooperatives, special financing bodies and government. Non-organized ones include land owners, merchants, and usurers. Regarding organized financers, betterment of repayment conditions might be considered. Especially in case of governmental finance, it is necessary to pay attention to the standard of finance selection. Noting such cases as the economic development in Thailand assisted by finance from overseas Chinese and foreign capital, we must also recognise the important role of non-organized financers.

Up to now various agricultural financing systems have performed an immeasurable role in the agricultural mechanization of the developing countries. But at this moment it is needed to reconsider the merits and demerits, the losses and profits, and the desirable new future role of agricultural credit. Even in Japan of today, financing for agriculture and agricultural materials is not yet considered satisfactory.

Whenever progress of agricultural mechanization is mentioned, it is agreed that real advances will not be made without improvements in financing. Of course, the "ought to be" of the agricultural machinery finance system cannot be decided in isolation. Needless to say, it should be realised in integral coordination with such factors as agricultural finance, national economies of the future, variation of industrial structure, laws related to tax, land ownership system, peasant system, and so on.

In order to promote introduction of agricultural machinery and to lighten the farmer's financial burden these measures are needed:

1. Promotion, utilizing government aid.
2. Enlargement of installment purchase and financing organization.
3. Firm establishment of credit enterprise system.
4. Set up of loan system.

In addition, close ties between financing from developed countries and government of developing countries is eagerly expected.

Training of maintenance mechanics

Generally speaking, agricultural machinery in Asian countries is in the stage of experimental utilization at present. Japanese manufacturers of agricultural machinery have been endeavoring for the diffusion of it in these countries for many years, and have given considerable cost and effort to such matters as after-care.

Along with education and training of farmers (and users), training of maintenance mechanics is one of the urgent important conditions in checking and repair of machinery. In this regard, responsibility of manufacturers is very great. However, the achievement of training maintenance mechanics greatly depends on assistance between governments of both developed and developing countries.

Bringing up extension servicemen

Public relations for the promotion of machinery must have more active development than in the past. It depends greatly on cooperation and back-up by the government.

Agricultural technic in developed countries has changed its "ought to be" in accordance with the development of agricultural machinery. In the case of Asian countries it is fair to promote agricultural mechanization in accordance with present land condition and agricultural technic. In the near future, however, agricultural technic and agricultural mechanization will need to change in coordinated ways. Elimination of anxiety about changing traditional farming practice to mechanized farming also largely depends on replenishment of extension servicemen.

Expansion of agricultural machinery training centers

For the purpose of training higher level technicians and improving agricultural machinery service, it is necessary to strengthen and widen the scope of existing training centers and establish new centers.

Establishment of circulation bases

At present, manufacturers put priority on setting up of agents to offer after-service. In addition, establishment of circulation bases is needed to furnish control and maintenance of machinery and spare parts and repair facilities. In this regard, along with makers' effort, cooperation of government organization is largely required. In Taiwan, R.O.K., and Thailand circulation expenses of agricultural machinery are not approved, and this is preventing establishment of circulation bases.

Setting up information exchange centers

It is requested that governments strengthen information collecting functions so that one can investigate required information and data prior to making an investment. Also, concentration of various information related to agriculture and machinery for all Asian countries at one place is badly needed for manufacturers to make more effective study and refer to primary data in the development of new machinery.

Major manufacturers have already been collecting information energetically through the effort of resident company staff, local agents, local companies and trading companies overseas. Also, Japanese manufacturers frequently participate in research teams formed by U.N. and government organizations. But it cannot be said that this is sufficient to insure practical use of information.

Establishment of agricultural machinery study organization

Establishment of an investigation, research and development organization exclusively for Asian countries is seriously needed.

Avoidance of rapid percentage increase of home production in Asian countries

It is well understood that from the view point of saving foreign exchange, employment promotion, industrialization progress and, furthermore, national consciousness of the country, it may be unavoidable each year to increase the percentage of home production. However, it is clear at present that because of delay in getting satisfactory performance from all of the required subcontractor factories, various frictions have been observed.

Prudent consideration is desirable before too rapid a response to the demand for more home production. When home production is realised it is apt to generate a ban on imports or radically high tariff rates for importing completed goods.

Governments of importing country may also limit imported goods by reason of standardization, and instead require presentation of a home production scheme. And in case it is an unsatisfactory scheme, importation will then be prohibited as an obstacle to standardization. Moreover, difficulties may be made over obtaining import licenses from the government of the importing country. In Asia, on the whole, the original manufacturer is usually limited in a joint venture to less than 50 per cent share, making it difficult to exercise leadership authority and eventually inviting difficulty to manage the business effectively. In the event of joint-venture, selection of the partner is treated as of highest importance because of this legal restriction.

Japanese manufacturers of farm machinery receive various requests from overseas users, government offices concerned, and Japanese cooperators overseas. They emphasize the need for machines to be durable, reasonably priced, and easy to operate and of simple structure. Complaints arise from insufficient supply of spare parts, lack of sufficient after-care, and frequent model change.

Needless to say, Japanese manufacturers who lead agricultural development and build machinery for the agricultural mechanization of Asian countries must modify and develop machinery suited to particular conditions in Asian farming. Even if present machinery is suitable for the purpose of turning potential demand to effective demand, the above-mentioned marketing conditions should be considered continuously in future designs. Undue pessimism about potential demand can be a source of regret.

As a matter of fact, one of our most important assignments is to ascertain continuously potential and effective demand, to catch the time of transition from potential to effective, and to move forward the effectuation promotion policy. To tell the truth, the approach to Asian countries by Japanese manufacturers prior to the last War was made in terms of "some day" or "in the near future". Up to date, however, none of them has rung the bell of the cash register.

The agricultural machinery market in Asia is vast and yet countless technical systems are demanded. No maker has succeeded in occupying a particular market with already existing machinery nor in shortening the time tunnel between potential and effective demand. This proves that the systematic collection and digesting of information are indispensable conditions to catch the transition time from potential to effective and to grasp the scale of demand.

Regarding governmental credit, technical cooperation, and private investment in the field of economic development, its function may differ in accordance with the situation of different countries. In regard to private investment, in addition to the merit of absorbing unemployment, the skills introduced with investment are highly prized. What is introduced in this way covers not only industrial technic but also procedural administration, business administration, training of local people, and particular study. Its role in such wide dissemination of technic strikingly heightens the importance of private investment in the field of economic cooperation.

To date, most investing enterprises of Japan in other Asian countries have been encouraged for their value in developing resources-import substitution. Few aim to process products and export accordingly.

On the other hand, saving of transportation and warehouse charges and closer relation with overseas markets will strengthen factors leading to lower production cost. And these environments will encourage Japanese manufacturers to operate in the overseas market more and more. When we look to the future, Japanese enterprises, most probably due to limits on space and supply of labour at home, will spread out their activities to the whole Asian region. And it is imaginable that from these areas finished consumable goods and machinery spare parts will then be imported to Japan. Moreover, primary products once imported as raw materials would be processed abroad and imported after finishing.

Asian countries deem Japan as their largest potential export market, and expect to see export expansion. Be the development-import what it may, such kind of after-process import by Japanese enterprises will benefit both parties.

From such a view point, the role of agricultural machinery performance would surely be remarkable, we believe.

Today, agriculture in the developed countries has moved rapidly in the course of qualitative conversion from labour intensive to capital intensive. The conversion resulted from internal and external factors: the outflow of agricultural population and also the changes in agricultural policy. The policy of "producer first" in the 1950s and early 1960s no longer has enough persuasive power from the standpoint of consumer administration.

Science and technology have made great progress, and their results are directly accepted in agriculture to produce more and more agricultural products by less labour with help of new equipment and improved productive goods. In other words, we are making progress steadily in the modernization of agriculture.

In contrast to the agricultural conversion in developed countries, the present situation of mechanization in Asia is such that the recent increases have been mostly in use of the power thresher and cultivator. In general, manual farming implements such as plow, hoe, and manual thresher still prevail.

In the agricultural mechanization of Asia, and especially in rice production, there was long dispute between the system of Europe mainly using large tractors and the system of Japan using medium and small sized machinery. Administrators and users are considering the system of large tractors for plantation and estate agriculture. For rice growing the decision has generally been to mechanize by using smaller machinery systems with the power tiller playing a main role. What all agree on is the need to make an effort to lift up productivity and bring down production cost. For this purpose we must take collective measures to accomplish integral objects such as technic diffusion, selection and improvement of suitable seeds, irrigation system, transportation, preservation and finance. And we Japanese manufacturers are ready to participate in the agricultural development of Asian nations.

It took 40 to 50 years to mechanize the agriculture of Japan, while few other Asian countries started before about 10 years ago.

Japan created an agricultural mechanization system by improving and reforming machinery, taking western advanced nations as a model.

It is desirable to seek agricultural mechanization systems to match the actual conditions of Asia, making efforts to fill the information gap and the agricultural management and the technology gaps, etc. This is why we want to increase our contribution to mechanization by promoting a better understanding of the present situation of agriculture in Asia.

It is obvious that the prosperity of Japan greatly depends upon the peace of the world, and especially upon the economic development of nations in Asia. As the prosperity of agriculture plays an important part in economic development, we desire to contribute to high productivity while releasing the farmer from hard labor.

WHAT WE HAVE LEARNED

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During the past eight days, including three days of field observations, we have gathered here in Japan to discuss one of the most important subjects of modernized farming in East Asia. Our workshop papers and discussions have presented many problems concerning farm mechanization in developing countries. Though we may not have made great progress in finding solutions to these problems—or even in devising new research approaches to solving them—the discussions of the problems themselves have helped to clarify our thinking. We have presented so many papers and discussed so many problems that it is rather difficult for me to include all the good points in a summary. Perhaps it may be easier for me to summarize the problems as a series of dilemmas.

Problems and Issues in Farm Mechanization

1. *Small farm size*

In most countries in East Asia farm size is rather small, and there is no reason to expect any dramatic increase in the area of the average farmer's holding. At the same time, from the technical standpoint, large machines are generally regarded as more efficient than small machines. But large machines require relatively large capital investment. They are economical only if they can be used in sufficiently large-scale farm operations. They are not economical for ownership by the individual small-scale farmer for use only on his own farm. For him, efficient use of machinery requires group action to provide large-scale operating units suited to the large machines, such as custom work arrangements or group ownership and joint conduct of farming operations.

However, development of group arrangements takes time and effort. In particular, establishment of joint farming requires structural, organizational, or institutional changes that present many difficulties. This is not just a farm management or purely economic problem. It also involves changes in rural leadership and social structure.

Based on the experience in Japan, the horsepower of farm machinery steadily becomes bigger and bigger. Now, the question is: must each country go through the evolutionary process of Japan, with widespread ownership of small machines? Or can the cost of this process be avoided by moving directly to some kind of shared use of large-scale, more efficient machinery?

2. *Specialized or multi-purpose machines?*

A somewhat similar question relates to the types of machines. From the technical standpoint, machines specially designed for particular tasks can perform better and more efficiently. Much engineering effort has gone into highly sophisticated design of highly specialized machinery. But the question arises in regard to spreading the high overhead cost of such machines. Simple machines, capable, with appropriate attachments, of use for a wide variety of purposes, may be more economical, especially if they are to be used by farmers with limited mechanical experience.

Regarding these points, I would like to say that Japanese farmers are more lucky than farmers in most developing countries, because they have much wider choice in selecting machines of different horsepower and scale and different types of machines. In this aspect, the efforts of farm machinery companies in Japan must be commended.

3. *Over-investment problem*

In our workshop we have discussed various aspects of this problem:

(a) From the micro point of view, based on individual farm operation and management, we analyze this problem on the basis of cost, profit, etc. Even here, what may appear to be over-investment when analyzed in terms of the farm business alone may not be over-investment when analyzed in terms of total family income. As described later, the use of machinery may make possible the increase of family income from off-farm sources.

(b) From the macro point of view we are concerned with:

(1) Labor mobility and its alternative uses,
(2) The contribution to the whole economy of labor moved out of agriculture,
(3) The relationships between the agricultural sector and other economic sectors,
(4) Structural change and increase in agricultural production potential by introducing farm machines,
(5) The allocation of total economic resources.

Government Policy Relating to Farm Mechanization

Governments of developing countries are concerned with agricultural modernization to enlarge the production potential, and are concerned with mechanization as a factor contributing to this development. In view of urgent needs of farm mechanization, the governments are seeking to play a positive role to accelerate the process. Government programs in this connection include:

(1) *Provision of loans for purchasing farm machinery.* Farm mechanization needs a great deal of capital investment, and farmers will not be able to buy machines if they can not get sufficient loans. Therefore, the government has to provide them sufficient loans with favorable terms of credit.

(2) *Provision of subsidies to farmers:* Since the purchasing power of farmers is relatively low, government subsidies will be very useful in stimulating the farmers to procure machines.

(3) *Investment in research experiments and training.* Technical know-how is a necessary condition for promoting farm mechanization. Governments therefore are investing in research experiments and in training machinery technicians.

(4) *Land improvement.* The fragmentation of farm land is an obstacle to use of farm machinery. Land consolidation and other improvements can remove this obstacle and facilitate farm mechanization.

(5) *Guidance in the supply of farm machinery.* Various farm machines which are adaptable to local conditions should be developed. Governments may assist the local farm machinery manufacturers to produce such machines or may import the proper machines from other countries.

However, some questions still need to be considered with regard to policy-making.

1. *Form of financial aid*

Assuming that the high price of machines is a factor retarding mechanization, should lower-price machines be subsidized by government? Or if lack of capital is a retarding factor, should agricultural credit be provided at low interest rates?

2. *Eligibility for aid*

To whom should aid or encouragement be given? To individual farmers generally? Or only in connection with special projects of land improvement, land consolidation or settlement? Or should government aid be given only to joint-operation or cooperative schemes, etc., that permit use of large-size machinery? Should government encouragement be given for all types of enterprise, or only for production increase of particular crops, such as rice?

These questions involve the place of mechanization within the overall agricultural development program, and its interrelationship with other parts of the program. Such decisions are concerned with the allocation of present government expenditures among different programs, and they should be made with consideration of longer-range objectives regarding the kind of agriculture to be established and the degree of guidance or control over the mechanization process which the government intends to provide.

3. *Incidence of costs*

Finally we come to the question: Who should pay for mechanization? How should costs be allocated among farmers, consumers, and taxpayers?

The allocation of costs depends not only upon direct government expenditures for mechanization programs but also upon other policies. Concerning the price of rice, for example, presumably, a sufficiently high price of rice to consumers would provide farm income sufficient to pay for machinery.

Subsidizing farmers' purchase of machinery may, in effect, be an alternative to high prices of farm products.

In general, the relative incidence of costs of alternative programs needs careful analysis as a basis for intelligent decision making.

Research Needs and Methods

1. *Farm management aspects*

Many problems of mechanization can be analyzed through farm management studies. The individual farmer contemplating mechanization must consider whether to buy machinery, whether to hire machine work done, whether to join a joint-operation group in which machinery will be owned and machinery services provided cooperatively. He needs to estimate whether use of machinery will add more to total family income than the costs involved. The following questions are important:

(1) *Costs of ownership and operation.* How high is the purchase price of the machine? On what terms can credit be obtained to finance it? How much does it cost to operate—including not only cost of fuel, etc., but also probable costs of maintenance and repair service, replacement parts, etc.? How promptly can competent repair services be obtained when needed? Costs must similarly be estimated in the case of hiring custom work or of joint ownership of machinery.

(2) *Cost savings.* Perhaps the most important incentive to machinery purchase is the saving in cost of labor that must otherwise be hired during peak seasons. In rice production, these peaks come at planting time and harvest time. There was great interest during the workshop in the progress of developing transplanting machines and harvesting and threshing machines. Overcoming these two bottlenecks will help greatly to release farm labor for other employments.

(3) *Other income-increasing potential.* Saving of labor during peak seasons is only part of the picture. Mechanization may make possible added income (a) through higher yields, as from deeper plowing; (b) through making additional farming enterprises possible with available family labor—multiple cropping, or livestock enterprises; (c) through making off-farm income possible for some family members, as in part-time farming. In this category, performance of custom work for others may be an important source of income that at the same time reduces cost by spreading the overhead cost of machinery. (Several persons pointed out, however, that income from this source declines as machinery ownership becomes more widespread.)

(4) *Reorganization of farming systems.* The economics of mechanization depends upon imagination and ability in devising new orientations of the whole farm business to take maximum advantage of machines and of the labor time freed by their use.

All of these questions should be studied to provide a basis for competent guidance to farmers. Methods of studying them were discussed and examples were presented in the workshop. A conventional approach is by cost accounting analysis. The budgeting method can be used for analyzing the total repercussion on farm organization caused by the introduction of machinery. Production functions can be developed, based on large-sample farm survey data, and optimum combinations of resources, such as labor and machinery, can be determined from the marginal value productivities.

Linear programming was likewise presented and discussed as a method for analyzing (1) the total effects on farm organization caused by the machinery introduced or (2) the optimum farm plan with the purchase of farm machinery.

2. *Macro-level analysis*

All of these methods are widely used for analysis of management of the individual farm, at the micro level. However, as mentioned before in connection with the over-investment problem, in dealing with farm mechanization we are also concerned with the aggregative or macro viewpoint.

Imaginative use of farm management analysis can shed light also on problems at the macro level. For example, in farm management studies, prices are customarily regarded as "given" —as exogenous variables. For the guidance of policy, they may be considered as endogenous, policy-controlled variables, in order to determine, for example, the degree of price subsidy necessary to encourage desired levels of mechanization.

For analyzing macro-level problems, one participant suggested use of the method of "systems analysis". This method should be emphasized.

3. *Non-economic aspects*

Machines not only save labor but also do work that cannot be done by human or animal energy alone. They also lighten the physical burden of farm work. This saving of energy in physical toil makes life easier for farmers. It may also enable the farmer to devote more time and energy to effective planning and management. Reduction in the necessity for women to work in the field may also bring improvements in household management and home life.

Farmers' desire to purchase machinery may be colored by the feeling that status or prestige in the community is enhanced by machine ownership. They may also feel that participation in cooperative or joint-operation schemes restricts management freedom and independence.

Such considerations may influence farmers' decisions related to mechanization. This aspect is not susceptible to conventional methods of economic analysis. The methods of attitude or opinion surveys may throw light upon the importance of such views among farmers.

The progress of mechanization brings about important changes in farming and in rural community life. As previously mentioned, it is a factor in such developments as land improvement projects and joint-operation schemes that alter the traditional patterns of rural organization.

Land tenure laws and the growth of speculative land markets, in which farm land values are divorced from their basis of agricultural productivity, may influence the process of mechanization. In Japan, particularly in suburban areas, mechanization has been associated with the growth of part-time farming and the process of urbanization.

Such aspects as these may be studied in part by methods of economic analysis. To obtain more complete understanding, however, particularly of the transformation of rural family and community structure under the impact of mechanization and related processes of modernization, the methods of rural sociological analysis appear to be needed.

Conclusion

The workshop papers and discussions have illuminated a broad spectrum of economic and social aspects of mechanization. The problems considered range from those of the individual farmer deciding whether purchase of a machine will be profitable to those of government policy regarding measures to accelerate mechanization.

From one viewpoint, the demand for mechanization is a response to the impact of industrial growth that draws workers out of agriculture and causes labor shortage during peak seasons. Viewed from the other side, mechanization is a means by which labor can be freed from the agricultural sector for employment in the expanding industrial sector.

The engineering characteristics of farm machinery may require transformations of farming systems and of rural society in order to take best advantage of mechanization. But mechanization is only one component of the modernization of agriculture to fulfill the needs of the developing economy. We must seek to fit mechanization into an orderly process of agricultural and economic development.

Because farm mechanization began earlier in Japan, and has progressed much farther than elsewhere in Asia, other countries should be able to draw valuable lessons from Japanese experience. For this purpose, however, each country must interpret past Japanese experience in light of its own present needs and conditions. The history of mechanization in Japan may provide guides to follow. Study of it may also suggest pitfalls to avoid, or short-cuts that can accelerate development in other countries.

How best to accelerate farm mechanization is considered an urgent problem in Asian countries. Many kinds of research are needed in order to deal with this problem effectively. Socio-economic research lags behind technology.

On the economic side, we are best equipped to deal with the micro-economic problems of farm management. The situation is less satisfactory with regard to ways of reorganizing farm production on a scale to achieve most efficient use of machinery.

On the macro-economic and sociological levels, we recognize many problems but we have only begun to formulate these problems in research terms that enable us to attack them effectively.

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