PN-AAN-561
ISN: 31753

THE CONSEQUENCES OF SMALL RICE FARM MECHANIZATION PROJECT

Working Paper No. 15

MECHANIZATION OF RICE PRODUCTION IN DEVELOPING ASIAN COUNTRIES: PERSPECTIVE, EVIDENCE AND ISSUES

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1981

The Consequences of Small Rice Farm Mechanization Project is supported by the United States Agency for International Development under Contract tac-1466 and Grant No. 931-1026.01 and is being implemented by the International Rice Research Institute and the Agricultural Development Council, Inc.

ABSTRACT

A generalized sequence of mechanization of the Asian rice production process is developed, based on experience in Japan, Taiwan and Korea, countries which by 1978 had reached a relatively high level of mechanized rice land preparation. Labor force growth rates are contrasted across Asian countries. A net social benefits model for evaluating the desirability of mechanizing rice production is outlined and factors often neglected are identified. Available empirical evidence on some important factors is reviewed. In closing, the most critical issues for evaluating the economic consequences of mechanization are stated.

INTRODUCTION

There is considerable controversy as to the desirability of agricultural mechanization in Asia. One extreme point of view equates mechanization with modernization so that it becomes the major indicator and requirement for development.[1] A more moderate view holds that the functional relationship between power input and agricultural output is analogous to that of fertilizer and yield so that development requires added power in the form of mechanization.[2] A third view holds that the major agricultural resource use question in the developing countries of Asia is the absorption of the significantly increasing numbers of laborers in the agricultural sector over the next 20 years and that mechanization of agriculture can help the absorption problem through the intensification of land use.[3] In this view, mechanization is the key to overcoming labor bottlenecks which prevent increased cropping intensity which in turn will permit the labor to be absorbed at other times during the production cycle. A major benefit of mechanization then is the increased agricultural output that can be generated through mechanization from the increased harvested area and even from higher yields that may result from deeper plowing and better cultivation practices. A fourth view, somewhat different from those outlined above, opposes agricultural mechanization in Asia on the grounds that it represents a straight-forward substitution of capital for labor and that under the labor supply circumstances existing in most Asian countries any such substitution is socially undesirable.[4] In some cases this is supplemented with the idea that distortions in the price ratio of labor to capital have been a primary factor responsible for speeding mechanization and that non-market forces have been responsible for a large degree of the distortion.

The purpose of this paper is threefold:

(1) to provide a perspective on the issues through an examination of the historical experience of East Asia;

(2) to provide a framework for criteria to judge the impact of the introduction of machinery or other technological changes;

(3) to examine the evidence from the available empirical studies on the economic consequences of the introduction of small scale machinery in rice production in South and Southeast Asia.

One further introductory note: mechanization means different things in different situations, so it is best to define how it is used. The relevant classification of technique for this discussion is based on power source: human, animal, and mechanical. Obviously machines can be used with any source of power, and one concept of mechanization is

the provision of tools, equipment, and simple machines for use with human and animal power. Our discussion, however, deals with powered equipment, and for the most part with two-wheel tractors or "power tillers," and power threshers.

THE PATTERN OF MECHANIZATION IN ASIAN RICE PRODUCTION

Economic, technical and policy factors are all important in determining the pattern and speed with which rice production is mechanized in a country. Alternative investment opportunities and the prices of land, labor and capital influence farmers' demand for machinery. The perceived social opportunity costs of those resources influence policies which restrain or encourage mechanization, and the relative abundance of resources influences their private and social costs. Technical factors such as the amount of power required for a given task, the degree of judgement needed to apply the power and whether the task requires moving through the field all influence the engineering feasibility[5] and hence the relative cost of mechanizing particular rice production tasks. Climatic or soil conditions also may influence the relative difficulty of designing successful machines.

A generalized sequence of mechanization.

Given that every country in Asia differs in its technical and economic conditions from every other one, it is unlikely that an identical pattern of mechanization will be observed across all. However, the broad similarities in relative factor abundance and the tasks required for wet-rice cultivation are such that a general pattern of rice mechanization is likely to emerge. To date, among the Asian rice economies, only Japan has fully mechanized its production system. Australian and North American rice production is fully mechanized, following a distinctly capital intensive line using large tractors, airplanes and combines, but it seems clear that most Asian countries will follow the Japanese pattern much more closely than the Western. Taiwan and Korea are well started toward mechanization following the Japanese pattern, and a number of other Asian countries are beginning to move in the same direction.

In East Asia, investment in land improvements and water control preceeded any move to mechanize production operations. This was partly an accident of history: improved water control was carried out using human and draft animal power, and was one of the few ways to improve the productivity of agricultural land in the high man: land economics of East Asia. Most of Japan's rice fields were supplied with irrigation

facilities by the 19th Century, and the major subsequent improvement was investment in drainage, providing the capacity to control water to a very high degree.[6]

The same water control investment occurred somewhat later in Korea and Taiwan, where there were "many years of rural infrastructure creation"[7] prior to WWII. Most of this infrastructure took the form of gravity irrigation and drainage. But with the availability of electricity and internal combustion engines, power pumps have become one of the first machinery investment for many rice producers. In areas of South and Southeast Asia where gravity systems are inadequate to permit efficient water control and groundwater resources are available, there has been substantial investment in private pumps.[8] Electric irrigation pumps replaced foot operated pumps in Japan during the 1920s, long before power tillers were used.[9] A 1966 study in an intensive double rice cropping area in Taiwan noted that one water pump was available for every three farms while there was only one power tiller for every 18 farms.[10]

In addition to pumps, other investments in land were important prerequisites for successful development of mechanized systems in East Asia. Drainage to provide a hard enough soil base so machines can work, enlargement of plots and consolidation of fragments, and construction of farm roads to reach individual plots were all important developments in some areas.[11]

After development of the high quality land base, small human powered threshing machines were among the first mechanical devices to be widely adopted.[12] These simple foot pedal threshers, were later introduced to a number of other countries by the Chinese and Japanese, but they never became established. When power threshers were developed, however, they were widely adopted in both East Asia and in some areas of other countries. Threshing seems particularly suited to mechanization on a technical basis -- it requires fairly large amount of power, is carried out in one location and requires relatively little judgment. Perhaps this is an important reason why threshers have been successfully introduced into a number of different economic situations.

The introduction of land preparation equipment sometimes preceeds and sometimes follows threshers. In Japan, two wheel power tillers were introduced in the early 1950s. Land preparation was the first operation mechanized in parts of the Philippines and Thailand, preceeding threshing there. Tillers may initially be very small as in the case of the 2-3 hp "iron cow" introduced in Taiwan,[13] but after some years machines in the 8-12 hp range seem to take over.

After mechanization of land preparation and threshing attention is directed at the other tasks in rice cultivation. It seems to be substantially more difficult to develop appropriate machines for planting, fertilizing, cultivating and drying. An appropriate combine has also proven elusive. These operations present formidable technical problems. Weeding, for example, requires considerable judgement and relatively little power. Some mechanical weeders have been developed, but herbicides have proven to be cheaper and more effective at distinguishing weeds from rice. Transplanting has been mechanized in Japan, but it requires special techniques for raising seedlings and is still quite labor intensive. There is a continuing discussion over whether direct seeding methods can be developed that are competitive with transplanting, but yields usually suffer. Despite these problems, by the late 1970s the Japanese had developed commercial machines for each major operation.

There are substantial divergences from this path. Four-wheel tractors of the 35-60 hp size have been introduced into Thailand, Malaysia, the Philippines and Pakistan. These units are used on a rental basis by small farmers in some areas for the initial land preparation with secondary land preparation carried out using draft cattle. Thus, old and new technologies co-exist. The large tractors have in some cases preceeded the development of a high degree of water control as in Central Luzon or Central Thailand where their presence in sugarcane farming may have stimulated their adaptation for rice. In other cases, government authorities (such as the Muda River Development Authority of Malaysia) may own the tractors and provide their services to farmers on a rental basis.

Data to measure the degree of mechanization and forces contributing to mechanization are somewhat fragmentary. The FAO publish data on "wheel and crawler tractors," "garden tractors" and a few other kinds of machinery, but there are many gaps in the series for Asian countries, the definitions are unclear and may be inconsistent from country to country. Time series data on the number of power tillers and farm wage rates is available for Japan, Taiwan and Korea for a number of years, although the wage rates are incomplete for Taiwan. Still, the data provide enough clues to begin to see the importance of certain forces in the mechanization process.

An oversimplified but still useful view can be obtained from a supply and demand model. Rice production machinery can be supplied either by imports or from domestic production. Imports are generally under government limitation or licensing. Domestic production may occur through private initiative, but experience in Japan and Taiwan shows that concessional government credit, subsidies, tax exemptions, and government development efforts have been major forces speeding the development of machinery appropriate to rice production conditions in those countries.[14]

Supply of machinery from the private sector is a function of the stage of development of the industrial sector and the alternative earnings opportunities for industrial capacity. The latter is related to the scale of investment needed to begin production of farm machinery compared to other industrial products. Potential earnings of export industries may make governments willing to set policies that encourage or discourage the mechanization of agriculture. Government investment in research and development of farm machinery is an obvious encouragement, while taxation and import restriction are barriers.

Thus, there are many ways in which government policies affect the supply of agricultural machinery and it almost seems possible to state that government policies determine the supply of agricultural machinery. Of course, there are limitations to the extent to which governments will subsidize imported machinery or invest in research and development of machinery. Recognizing those limitations one might better say that the supply of agricultural machinery is determined by market forces in the industrial sector together with the decisions of government to tax or subsidize imported machinery.

The demand for rice production machinery is determined by the technical productivity of the machinery -- the degeee to which it substitutes for labor or other inputs -- and the relative price of labor to substitutes, and the price of rice. Machinery well adapted to the technical requirements of a particular agricultural setting will, by definition, be more productive and substitute for a greater value of alternative inputs and thereby be subject to greater demand than poorly adapted machinery. A high price of rice will increase the demand for machinery relative to demand with a low price of rice.

The data in Table 1 are broadly consistent with the above static equilibrium concepts, although there are many other forces within each country that determine the level of mechanization. The data show that Japan is far and away the most highly mechanized country of the region. In the early 1970s it had 6 power tillers for every 10 hectares of crop land and 5 tractors for every 100 hectares. Farm wage rates were approaching $10 per day and the price of rice was the highest anywhere in the world. Taiwan and Korea had wage rates about four times as high as any other country except Japan and were well started toward the adoption of power tillers. Korea had the second highest rice price and Taiwan's was not far behind.

Several countries had a small number of tractors, but these are either used for road transportation, plantation, or other non-rice crops (Sri Lanka and Malaysia), or on a contract basis for the initial land preparation operation on rice(Malaysia, Philippines, Thailand). Power tillers had been introduced in small numbers in many countries, but aside

from China, Thailand and the Philippines, they were still available in strictly experimental numbers. Wage rates and rice prices in most South and Southeast Asian countries, with the possible exception of Malaysia were far from those existing in the East Asian countries, and hence it appears that rice production in most of South and Southeast Asia was not poised for rapid mechanization. However, despite the fact that Japan was so far ahead of the other Asian countries, it still appears to be a useful case to examine in detail for lessons that may be relevant for the rest of Asia.

Japan experience

In 1950 Japan s agriculture was just entering the early stages of mechanization with many small pedal threshers, some 13,000 power tillers and an equal number of power sprayers, but essentially no other machinery. Japan's industrial sector, recovering from WWII, was beginning to pull increasing numbers of workers from its rural areas. Thirty years later over 4 million power tillers were being used and rice production from transplanting to harvesting was essentially mechanized. The pattern of mechanization over the 30 year period from 1950 to 1980 is shown in Table 2.

In 1950, Japan had about two power tillers for every 1000 hectares of crop land. Early data on threshers is not available, but in 1955 there was one thresher for every 3 hectares. Through the 1950s the number of tillers increased gradually, so that by 1960 there was one tiller for every 12 hectares and one thresher for every 2.5 hectares. During the 1960s the size and capacity of Japanese tillers increased and the riding tiller was introduced. By 1970 there was one tiller for every 1.7 hectares, apparently more than an adequate number. Thereafter, the number of ordinary walking tillers remained constant while there was a rapid increase in the number of riding tillers. The 1970s also saw the rapid introduction of powered rice transplanting machines and combine harvesters and the further increase of power sprayers and dusters. Power reapers and reaper-binders were also present in significant numbers during the 1960s although the data are fragmentary.

During the same period there was a sharp decline in the agricultural labor force in Japanese agriculture and a steady reduction in the hours of labor used per hectare in rice production.[15] During the period machines were substituted for human labor, the increase in machinery occuring together with a decrease in human labor input. Some observers clearly saw the trend toward mechanization as a drive to achieve economic efficiency pushed by rising labor costs, rather than as a continuation of the earlier Japanese drive to increase yields. For example, Tsuchiya claims that "mechanization has been advanced in order to secure a certain amount of rice at the lowest possible cost, rather than to increase the yield.[16]

Differences within East Asia

Korea and Taiwan are the only Asian rice producing countries other than Japan that had achieved any significant level of mechanization by 1980. The pattern of power tiller introduction in the three countries is shown in Figure 1.

In 1960 Taiwan had as many tillers per 1000 ha as Japan had in 1950, but the number increased more slowly. After 10 years of modestly increasing numbers, Taiwan still had only about 2 tillers for every 100 hectares. However, by 1977, 20 years after the initial introduction there was nearly 1 tiller for every 10 hectares, and by the 1980s nearly all of Taiwan's rice land was being prepared by machines. Power tillers were introduced into Korea's rice sector about a decade after they were first used in Taiwan, and their rapid adoption was similar to the Japanese case, reaching the 7 tiller-per-100-hectare level within about 10 years, and continuing to increase rapidly thereafter.

In these three countries it appears that adoption of tillers began to "take-off" when the number reached about 2.5 per 1000 hectares. Before that only experimentation was taking place, and that was probably concentrated in small areas near dealers and repair facilities. As such facilities increase and as the economic attractiveness of the machines increased with rising labor costs, the process of adoption progressed. There are strong similarities in the economic conditions that accompanied mechanization in the three East Asian countries, but there are some apparent difference as well (Table 3).

Four critical points in the process of mechanization are identified in Table 3: (i) experimentation, (ii) 2.5 tillers per 1000 hectares, when there are an obvious number of tillers but an insignificant proportion of land being served, (iii) 20 tillers per 1000 hectares when about 20% of the area can be served and there appears to be a take-off to mechanization, and (iv) 100 tillers per 1000 hectares when there are enough tillers to (theoretically) serve the entire rice area. The data for East Asia show great differences in the real agricultural wage measured in rice equivalent at the take-off mechanization. In Japan, it cost about 5 kg of rice per day of labor at the take-off stage, in Korea about 6 kg, and in Taiwan about 10 kg. These differences suggest that farm level demand for machinery must have been very different in the three countries. However, wage rates converted into kg of rice reflect the domestic price of rice as well as of labor. All three countries, indeed all Asian countries, insulate their rice prices from the world market, thereby distorting them in one direction or the other.

The industrial sectors of the three countries have, by contrast, been well aligned to opportunities in the international market. Thus it is argued that the costs of mechanization reflected the world market and the price of rice reflected policy views on how to achieve the desired pace of development. Japan, with a high rice price, mechanized rapidly even though farm wages were only 3-6 kg of rice in the 1950s.

Both labor and rice were so valuable as potential foreign exchange earners that were was a strong drive to mechanize. In addition, institutional factors in the form of restraints on land sales and consolidation to larger units encouraged the development of part-time farming which could only conveniently be carried on with machinery. Korea has followed a similar path, but with an even higher price of rice, encouraging rapid mechanization in the 1970s. Taiwan, in contrast to Korea, has had a low price of rice and has made possible maintenance of more labor on farm through rural industrialization policies, thus retarding mechanization.

THE DESIRABILITY OF MECHANIZING RICE PRODUCTION

The East Asian countries mechanized when the labor used in rice production became sufficiently valuable in its alternative industrial employment that it could no longer be used in the rice sector. The data in Table 1 indicate that only Malaysia, Thailand and Burma have ratios of agricultural wages to rice prices that approach those in the East Asian countries, but that the low value of rice in Thailand and Burma makes wages seem high. Thus, it appears that only Malaysia is in a position parallel to the East Asian countries with respect to mechanization and that on a comparative basis Malaysia may be the next country to adopt rice mechanization.

Labor force growth rates

This view is consistent with labor force projections for 1977-2000. By knowing the growth rate of the non-agricultural labor force, the total labor force, and agriculture's current share, one may calculate the growth rate of the agricultural labor force needed to absorb the available labor in the economy. This process can be understood by examining the following relationship.17

$$x = Z\,(1-a) + aY$$

where:

x = the rate of growth in the labor force as a whole,

Z = the rate of growth of the agricultural labor force,

Y = the rate of growth of the non-agricultural labor force,

a = the proportion of the labor force in the non-agricultural sector.

This relationship simply states that the rate of growth in the total labor force is weighted average of the rates of growth of the labor force in the two sectors of the economy. Given this one can easily ask what rates of growth are needed in the two sectors to achieve certain objectives. For example, one can calculate the rate of growth in non-agricultural employment required to absorb all the new entrants to the labor force. Conversely, one can ask how fast the agricultural labor force will grow given certain initial conditions. Because agriculture generally gets the residual labor, the relationship can be rewritten as:

$$X = \frac{x - aY}{1-a}$$

Thus, for a country with 25% of the labor force in the non-agricultural sector, a rate of growth of the non-agricultural labor force of 8%, and a 3% rate of growth in the total labor force, the relationship shows

$(3 - .25(8)) \div .75 = 1.33$, while a country with the same proportion in the non-agricultural sector and the same overall growth in total labor force but only a 5% growth in the non-agricultural sector shows $(3 - .25(5)) \div .75 = 2.33$.

Typical values for important Asian rice growing countries are shown in Table 4. The labor force growth rate in the non-agricultural sector is not readily available so we use the growth in urban population, which if anything overstates the rate of non-agricultural labor force growth. Countries that had an accelerating rate of population growth during the 1960s and 1970s have accelerating labor force projections through the year 2000. Those in which population grew more slowly in the 1970s than in the 1960s show a slowing of labor force growth rates in the future.

Among the Asian countries, only Korea, Taiwan and Japan have reached the stage of declining agricultural labor forces. Burma had a temporary decline in its agricultural labor force in the early 1970s because of a flight from agriculture caused by very low rice prices and because of earlier slow growth of population. This will change over the next two decades with the rise in the growth rate of the total labor force. All the other countries have added to their agricultural labor force at 1% per year or more during the 1970s and will continue to add 1 to 1.8% per year to their agricultural labor force over the next 20 years. Thus, the main rice producing countries of Asia have had and will continue to have increasing numbers of people available for rice production.

A social benefit:cost framework

Given the context of a growing supply of agricultural labor one must raise questions about the desirability of introducing machines that substitute for labor at this point in the development process of most Asian countries. Clearly, machinery is used for activities that could otherwise be carried out by labor, and thereby substitutes for that labor. However, the argument put forth by many that farm machinery may provide the key input necessary to overcome a labor bottleneck that prevents land use intensification is persuasive. For economies struggling with the problems of development, mechanization can only be justified if it pays own way by generating positive benefits for the society -- irrespective of the psychic benefits of seeing tractors being used in one's field. It is therefore appropriate to ask what are the benefits and costs of mechanization and how those costs and benefits are shared within the society. One formulation is to ask how mechanization would change the net social benefit generated in the agricultural sector. Net social benefit (NSB) is equal to agricultural output valued at shadow prices less agricultural inputs used in production valued at shadow prices:

$$NSB = Q_r P^*_r + Q_p P^*_p - L_r P^*_l - K_r P^*_k - T_r P^*_t - L_p P^*_l - K_p P^*_k - T_p P^*_t$$

Where the r and p subscripts refer to rice and other crops, respectively; Q's refer to output quantities produced; L, K and T refer to labor, capital and land respectively: and P*s are shadow of prices. Output can be further defined as the product of area harvested times average yield, while area harvested equals the geographic area times the cropping intensity. Defining C_r, the rice cropping intensity as the total area of rice harvested divided by the geographic crop area and C_p the other cropping intensity as the total area of other crops harvested divided by the geographic crop area gives

$$Q_r = C_r A Y_r \text{ and } Q_p = C_p A Y_p$$

where A is the geographic crop area, Y_r and Y_p are the yields per harvested hectare of rice and other crops and $C_r = A_r/A$, $C_p = A_p/A$.

Thus,

$$NSB = C_r A Y_r P^*_r + C_p A Y_p P^*_p - L_r P^*_l - K_r P^*_k - T_r P^*_t - L_p P^*_l - K_p P^*_k - T_p P^*_t$$

The impact of any particular change such as that generated by mechanization can be expressed as the total differential of NSB:

$$dNSB = AY_rP_r^* + dC_r + C_rAP_r^*dY_r + C_rAY_rdP_r^* + AY_pP_p^*\,dC_p + C_pAP_p^*dYp + C_pAY_pdP_p^*$$

$$- P_l^*dL_r - L_rdP_l^* - P_k^*\,dK_r - K_rdP_k^* - P_t^*dT_r - T_rdP_t^* - P_l^*dL_p - L_pdP_l^*$$

$$- P_k^*\,dK_p - K_pdP_k^* - P_t^*dT_p - T_pdP_t^*$$

Some components of the expression are expected to change dramatically with mechanization. These are the focus of most investigations on the impact of mechanization. Other components are commonly assumed to be constant while still others are generally ignored. A brief identification and classification may be useful.

P_r^*, P_p^* : The prices of rice and other crops are generally assumed to be invariant with the techniques of production, although if output effects of changes in technique are large, then these prices may change.

Y_r, C_r, Y_p, C_p : The production of rice and other crops may change as a result of changing yield and changing land use intensity.

A : The geographic crop areas is, as above, generally assumed to be fixed because there is little new land to be exploited except in a few remote areas. Area increases result largely from changes in cropping intensities.

P_l^*, P_k^*, P_t^* : The shadow prices of labor, capital (machinery) and land are generally considered to be invariant with respect to changes in production techniques. This assumption may be valid only in the short run where the rice production sector is small relative to total use of each input.

$P_i^* = P_i + D_i$: The shadow prices of inputs equal their market prices, P_i, plus a difference which may be recognized as a distortion factor, D_i.

L_r, K_r, T_r : The use of inputs in rice production is a major factor usually assumed to change with the introduction of technical change.

L_p, K_p, T_p : The use of inputs in production of other crops may also change with a change of technology, but these are usually ignored by most analysts.

Table 5 provides a convenient summary of the variables involved in the issue and two bases for their classification that may be useful.

Because of many of the factors that may potentially change have been ignored in the empirical work on the impact of mechanization, it is impossible to draw any firm conclusion from the work that has been reported, although the investigations to date do provide some indications as to the size of certain impacts.

A second dimension of the impact of mechanization, aside from the size of net social benefits, is the distribution of NSB among earners in the production process. There is relatively little insight available on this issue in the empirical literature, aside from the obvious statement that in a market directed economy one could surmise that laborers receive the returns to labor and farmers or capitalists receive the returns to capital. All consuming groups would obtain some portion of the benefits to increased output via its impact on the market price of rice.

Because the empirical studies have been cast in a much narrower framework than that suggested above, it is impossible to evaluate from them the NSB of any given change. However, a necessary (but not sufficient) condition for society to be benefited by the change is that

<u>either</u>

(a) the total output value of crops produced be increased with no change in value of inputs;

<u>or</u>

(b) that machinery be introduced where the social cost of labor is rising relative to the social cost of capital.

In either case the identified change will have a positive impact on the NSB, which will be reflected in a lower social cost of rice production. This lower social cost of output, if transmitted through the market would result in lower prices of rice. If neither condition holds then it is unlikely that there is any NSB from mechanization.

Net social benefit as used in the above discussion has only an efficiency implication, equity or overall social desirability is not inferred by either an increase or a decrease in NSB. Thus a situation that leads to an increase in NSB with a decrease in equity or a decrease in NSB with an increase in equity may be selected because society decides it is worthwhile to trade-off some equity for the efficiency thereby obtained. However, it seems evident that society would never knowingly

choose a situation that leads to a decrease in NSB and a decrease in equity. Given the existing price distortions (taxes, tariffs, subsidies, imperfect competition) in most developing economies it is likely that use of market prices to evaluate benefits may lead one to conclude that a given change leads to increased efficiency when it may lead to decreased efficiency. Thus the importance of using shadow prices cannot be overstressed if one seeks to evaluate NSB.

A general equilibrium framework.

Although the formulation of net social benefit in the preceeding section takes account of the impact on rice and other crops it is a single sector partial equilibrium model because it does not account for changes that may occur in the non-agricultural sector of the economy. That requires a whole economy or general equilibrium approach. If rice production uses machinery that is domestically manufactured, mechanization of rice production may generate considerable income and employment in the machinery sector. The amount of employment will vary with the labor intensity of machinery production as studies of the machinery manufacturing sector would confirm. One may also recognize that the increased income generated in manufacturing machines will generate an increased demand for rice. If that increased income is concentrated in the classes that have a high income elasticity of demand for rice, then the feedback impact on the rice sector will be larger than if the increased income went to classes with a low income elasticity of demand.

These interrelationships can be measured in an input-output model of the type developed by Leontief.[18] Input-output models (I-O) view the entire economy as a whole, in which all the inputs used in the production of each commodity in the economy are identified and measured. Manipulation of such models can lead to insights on the impact changes in one sector can have on other sectors.

A prototype I-O model for the Philippines has been developed that enables a determination of the effect of following various mechanization strategies for increasing rice production.[19] Thirteen rice production techniques which differ in irrigation source, land preparation power and threshing method are included. Production of power tillers, 4-wheel tractors (i.e. imports), and two sizes of axial flow threshers are included. The model calculates the direct and indirect effects on employment, resource use, imports and consumption of increased rice production obtained from any specified rice production technique.

Input-output analysis of this type has the advantage of being able to quantify both the direct employment impact of machines substituting for labor in rice production, as well as the indirect impact of

the increased labor used in producing, distributing and servicing the machines. Such models can be developed by building on existing I-O models, which planning ministries have already developed for most countries.

EVIDENCE ON THE IMPACT OF MECHANIZATION

In evaluating empirical data on the issue we concentrate on the impact of mechanization on output, then briefly consider who gains and who loses. The review concentrates on rice in developing Asian countries. All the studies are micro-level farm studies and most evaluate only one or two of the factors identified in Table 5.

Impact on Rice Output

There are many types of machinery, each with specific functions. To be useful the evaluation should be machine specific and should focus on those machines of most interest. It is clear that mechanical irrigation devices as they have been introduced into Asian rice production systems have the direct effect of improving yields and may also expand area harvested without displacing labor. There is general agreement on this and the questions that arise about irrigation relate to the relative investment cost.[20] Similarly, mechanical sprayers are used to carry out tasks that would not be done by hand. Such mechanical devices may be considered as yield increasing even though in some cases where water is extremely scarce, and labor extremely cheap, as in the historic case of China, water may be moved with human labor or insects may be removed manually. There are important questions about the most appropriate scale and design of yield increasing devices but because of the clear output increasing impact of such devices they meet the minimum test for socially beneficial technology suggested above.

In the review of evidence we focus on the impact of mechanized land preparation and mechanized threshing in rice or rice based systems. The large number of studies that have been done for wheat-based systems in South Asia are not reviewed here, Binswanger has done an excellent job with those.[21] Land preparation and threshing machinery has been recently introduced in a number of countries, the machines have obvious labor saving properties and are being promoted on the basis that they increase output by increasing cropping intensity, or increase yield by ensuring that the crop is planted or harvested at a more optimal time. Hence those machines are appropriate to evaluate.

There are two ways to empirically determine the impact of a change in technology: (1) comparing users with non-users, holding all other factors constant, and (2) tracing through the impact of a change on a

sample of users that have experienced only that change. Because the world is not a social laboratory in which other factors are constant, all empirical studies have some level of imperfection about them, but it is hoped that they approximate the ceteris parabus conditions.

Cropping intensity. Studies measuring cropping intensity impacts are summarized in Table 6. The first line for each study shows the cropping intensity under the unmechanized system, the second shows the change in cropping intensity that was associated with mechanization.

The King study is cited by Duff[22] to show the impact of mechanization on cropping intensity. It clearly indicates the dominance of quality of irrigation as contrasted to power tillers. The subsample with good irrigation who used carabao for land preparation harvested 1.74 crops per year. The farms with poor irrigation had just about one crop per year regardless of the use of carabao or power tillers. Evidence from a more recent study in Central Luzon shows stronger contrast between irrigated and rainfed farms, however, in this sample the farmers using tractors or power tillers for their first season's land preparation had higher cropping intensities that those using carabao.

Pudasaini found somewhat similar results in Bara District of Nepal -- farms with mechanized land preparation had about 12 and 14% higher cropping intensity than those using animals, whether irrigated with pumpsets or not. Two studies in India and one from Bangladesh showed modestly higher cropping intensity on mechanized farms, but the samples were not separated by water control. Farms using tractors had as much as 10% higher cropping intensities than those using bullocks for land preparation.

Studies in South Sulawesi and West Java, Indonesia reported the overall highest cropping intensities of the studies reviewed here. In South Sulawesi, one of the sparsely populated "outer islands" the researchers determined that almost no change occurred in cropping intensity on either rainfed or irrigated farms after the introduction of tractors for land preparation. It was clear that an extremely high level of intensity was achieved without tractors. The same result was reported in West Java.

Few data evaluating the impact of mechanized threshers are available. Those that have been found are summarized in Table 7. The results seem to be more variable than for land preparation. Especially surprising is the case of Central Luzon where farms using hand threshing had more intensive cropping patterns than farms using power threshing. Table 8 shows more complete data from this study in which information was obtained from 218 rice producing parcels. Approximately half the parcels had one crop per year while the other half grew two crops per year. Examination of the table shows that regardless of the method of land preparation the use of the large thresher (tilyadora) was associated with two crops of

rice per year, and that small thresher (axial flow) was used with about equal frequency on farms with one and two crops per year.

Yields. There are suggestions in the literature that mechanization of land preparation can lead to increased rice yields. "Certain yield increasing practices cannot be effectively and economically carried out by human power and manually operated tools and machines or by animal power ... many of the techniques that have been developed for dryland farming, and which have greatly increased area yields on dry lands cannot be applied where only human and animal power is available. 'Timeliness' in the performance of certain operations has a very great effect on area yields and it is in making possible the 'timeliness' of work that the greatest effect of mechanization on increasing yields is seen."[23]

Empirical data supporting these views are difficult to find. Perhaps the statements are primarily directed at the potential yield benefits in dryland agriculture. One field experiment comparing alternative land preparation techniques failed to show any difference in wetland rice yields (Table 9). There was a clear substitution of fuel (and capital) for labor hours, and there seemed to be some indication of fewer weeds with certain techniques, but yields were essentially identical for each of the 5 tested techniques.

Four years of record keeping data from two provinces shows that farmers using tractors reported somewhat higher yields in some cases, and somewhat lower yields in the others (Table 10). There were, however, relatively few farmers who used tractors. Pudasaini found that farms with pumpsets had yields of 2.1 t/ha and those with pumps and tractors had yields of 2.3 t/ha.[24] Bagyo found yields of 4.9 t/ha on tractor farms, 4.5 t/ha on manually cultivated farms and 4.7 t/ha on animal cultivated farms in the wet season.[25] A few other farm surveys that have compared yields on farms with mechanized and non-mechanized land preparation methods show similar results.[26] In such studies, however, it is unclear whether the source of yield increase is better cultivation or higher levels of other inputs like fertilizer. Many authors argue the latter are more important.

A second source of increased yields from mechanization is from timeliness. It is hypothesized that timeliness is improved on mechanized units thereby permitting farmers to take advantage of more optimal crop production conditions leading to higher yields. Pudasaini found "almost no difference in the paddy transplanting schedule of tractor hiring farmers following tractor use," in contrast to the earlier planting of wheat which they practiced after adopting tractors.[27] The Indonesian study referred to earlier provides a comparison of the percent of the area in which land preparation was completed each week on farms using various techniques (Fig. 2). These data fail to show any consistent support for the hypothesis that timeliness is significantly improved mechanization in those cases.

Table 11 summarizes evidence obtained from three years of record-keeping in Iloilo, Philippines. Relatively few farmers used tractor power, but there is no evidence that they enjoyed any timeliness advantage over those using carabao power. The week the first crop was planted was generally earlier on the plots cultivated by carabao for the first crop than on the tractor farms. The turnaround time between harvest of first crop and planting of second crop averaged 1.7 weeks on cabarao cultivated plots and 3.1 weeks on the tractor cultivated plots.

The general thrust of the limited evidence on output effects of power tillers and threshers suggests that tillers may contribute to an increase in cropping intensity of about 10%, but that threshers have little impact on intensity. Neither seem to have any clear effect on yields either through timeliness or shortening turnaround time.

Who gains from mechanization.

If mechanization results in increased output, that higher output will tend to push prices down and the benefits are shared widely by rice consumers, whether they be landless agricultural workers, farmers or urban people.[28] The absolute benefits to various individuals are positively related to the proportion of their incomes they spend on rice consumption.

In the absence of increased output, the adoption of machinery may shift earnings from one group to another. That is, a machine that replaces labor will receive the wage formerly paid to the laborers. In such an event the owner of the machine will receive the earnings of the machine. There is an inherent difference in the ownership pattern of capital and labor. In the absence of slavery, labor can only be owned at a rate of one unit per person, or at most 5 - 10 units per household. Ownership of capital, on the other hand, can be and in most economies is, concentrated in the hands of relatively few, usually through inheritance, political power or business acumen. The fact of concentrated capital ownership means that the income earned by capital also is concentrated. Thus, the introduction of machinery has redistributing effects, but when it also leads to increased output adds to the welfare of low income rice consumers and the adopters of technology. When machinery has no output effect, it simply redistributes income.

When a task can be accomplished more cheaply using machinery than with labor farmers will have the incentive to adopt the machine. However, if the machine is made cheaper than labor through subsidies on the purchase price or through low cost credit, then farmers are responding to artificially (policy-induced) market prices that diverge from the real, or shadow prices. If the machines result in a faster rate of output growth than would be achieved in their absence, then the policy maker must evaluate the trade off between more output and redistribution of income from labor to owners of capital. But if there is no output effect,

the decision to promote mechanization is a decision to support a transfer of income from labor to machinery owners, without an offsetting benefit.

The income redistribution effects of labor saving (private), cost reducing machines are substantially different in market directed economies of South and Southeast Asia from what they are in say the communally organized agriculture of the People's Republic of China. In the latter, any cost reductions are shared among all members of the commune in a manner decided upon by the commune. Thus, if introduction of a particular machine cuts down on costs, all benefit in proportion to work points earned. In market directed economies, the earnings of factors of production go to their owners so that whoever owns a machine will get the benefit of the reduction in cost achieved by its introduction.

The extent to which landless agricultural workers depend on earnings from hired farm employment varies widely from place to place. Under many conditions they are highly dependent on agriculture, and perhaps even more dependent on the earnings they obtain during the harvesting season. This is illustrated by the data in Table 12.

These data, from a very small study of 16 families in Iloilo show that the two groups of landless worker families obtained about 60% of their second season income from the share payment they received for harvesting. Cash wages were minimal as was non-farm income. Landless worker households show some small amount of savings while rice farmers have deficits in their overall six-month accounting. This is because five of the eight rice farmers were making installment payments for farm machines. Rice farmers have greater access to credit that can compensate for the observed dissaving over the six-month period.

In the situation depicted, farmers receive significant income by renting the services of their machines to other farmers and to landless workers. Landless receive 1/6 of the yield for harvesting and threshing a crop. If they use threshers, which some do, they pay 1/3 of 1/6 of the crop using mini-threshers. If the landless choose to purchase the services of the thresher, then one may surmise they are better off -- either because they can harvest a greater area in the time available or because they need put in less effort. If the farmer induces the harvesters to use the machines through threat of withdrawal of harvesting rights, then one may suppose the laborers are worse off but have little choice. If a reaper were to be introduced employment and income opportunities would decline even further.

In another Philippine study, Hayami, et.al. have shown that $411 of the total household income of $646 of landless workers came from rice received as wages.[29] Most of this comes as a share of the harvest, in payment both for harvesting and as a delayed payment for weeding activities conducted earlier in the season under "gama" contracts.

On the other hand, Singh claims that "non-farm activities in rural areas are a primary source of employment and earnings for approximately one-third of the rural labor force in most LDCs (one-third if we include rural towns) and are a significant source of secondary earnings espe- in the slack season for small farmers."[30]

Clearly, the actual impact on laborers of any reduction in the demand for labor depends on the proportion of their incomes that derive from operations that are mechanized and the opportunities for alternative earnings. This varies from place to place making the need for a careful assessment of the likely impact of mechanization that are much more important.

Critical Research Issues.

The brief review of empirical studies made in this paper is not put forth as conclusive, indeed one must draw just the opposite conclusion -- the results differ widely, depending on the country and system examined. As Gotsch puts it "most assessments have continued to omit a number of important institutional variables, the most notable having to do with the distribution of power and influence in the countryside.[31] Gotsch then quotes Griffin quoting Marshall Wolfe on what is called the fallacy of eclecticism, i.e. the indiscriminate use of bits and pieces of policies that are alledged to have been successful in other settings.[32] Given that there is indeed a fallacy of eclecticism, then one is forced to the conclusion that comprehensive studies are needed for each national environment for which policies are to be designed.

Many of the studies available prior to this conference ignore or only partially evaluate certain important issue. Some of these issues can be studied at the micro-level but others require macro-economic studies or analyses. I suggest that the following issues are among the most critical for understanding the impact of small rice farm machinery and should be kept in mind as we review the results of studies conducted as part of the Economic Consequences of Small Rice Farm Mechanizattion project. For a particular machine in a particular location:

1. Has the machine resulted in an increased yield per hectare or an increased cropping intensity? How has this been achieved -- i.e. is it a result of the machine or a result of a better total capital position of machine users? Is it the result of improved timeliness?

2. Is there a substantial change in the yearly average per hectare use of labor and capital associated with using the machine? Who are the owners of the capital and labor thereby affected? How large is the impact on their incomes?

3. Is there a substantial economic incentive to adopt the machine as judged on a private cost and returns basis? Would that incentive change if all inputs were priced at their shadow prices? Is there a significant net social benefit associated with using the machine?

Footnotes

[1] In the late 1970s the modernization of agriculture in the People's Republic of China was synonymous with mechanization. Those who point out the psychic benefits that obtain from riding a tractor rather than walking behind a carabao or from the alleviation of drudgery have similar ideas in mind.

[2] Javed Hamid, "Agricultural Mechanization: A Case for Fractional Technology," in Readings in Asian Farm Management, ed. Tan Bock Thiam and Shao-er Ong, (Singapore, U. of Singapore Press, 1979). H. Binswanger calls this the "net contribution" view in The Economics of Tractors in South Asia (New York, ADC and ICRISAT, 1978).

[3] As H.M. Southworth states the issue: "Substitution of machines for labor in peak periods could make possible more productive use of labor over the whole year," in "Some Dilemmas of Agricultural Mechanization," in Southworth and Barnett ed. Experience in Farm Mechanization in Southeast Asia, (A/D/C, New York, 1974).

[4] One of the more moderate statements of this position is K.C. Abercrombie, "Agricultural Mechanization and Employment in Developing Countries," in Effects of Farm Mechanization on Production and Employment (Rome, FAO, 1975).

[5] Thanks go to Professor Gil Levine for his succinct identification of power, judgement and mobility as critical factors in determining the technical feasibility of machinery design.

[6] Ishikawa identifies as the most common type of basic investment in land during the early phase of improvements in Japanese rice production the conversion of "wet rice fields" (shit zuden: rice lands which are left in a wet condition throughout the year because of the lack of drainage facilities) into "dry rice fields" (Kanden: rice lands which are kept in a dry condition during the non-rice-growing season) by installation of drainage facilities. (p. 157). Shigeru Ishikawa, Essays on Technology, Employment and Institutions in Economic Development, Economic Research Series No. 19, Institute of Economic Research, Hitotsubashi University (Tokyo, Kinokuniya Company, Ltd.) 1981.

[7] John C.H. Fei and Gustav Ranis, "Agriculture in Two Types of Open Economies" in Agriculture in Development Theory, ed. Lloyd Reynolds, (New Haven: Yale U. Press, 1975).

[8] S.M. Patel and K.U. Patel, Economics of Tubewell Irrigation, (Ahmedabad: Indian Institute of Management, 1971).

[9] Ishikawa op.cit. p. 44

[10] Weng-Chieh Lai, "Current Problems of Farm Management on Mechanized Farms," in Farm Mechanization in East Asia ed. Herman Southworth (New York: Agricultural Development Council, 1972).

[11] Keizo Tsuchiya, "Mechanization and Relations Between Farm, Non-Farm and Government Sectors," in Farm Mechanization in East Asia, ed. Herman Southworth (New York: Agricultural Development Council, 1972).

[12] The pattern holds in Korea also. C.C. Lee states that the manual thresher worked by two persons in which one keeps the drum turning and the other feed the grain is the most usual type of thresher in Korea. "Economic and Engineering Aspects of Mechanization of Rice Harvesting in Korea," in Southworth ed., Farm Mechanization in East Asia (New York:Agricultural Development Council, 1972).

[13] Carson Kung-Hsien Wu, "Analysis of Machinery-Labor Relationship in Farm Mechanization," in Farm Mechanization in East Asia, ed. Herman Southworth (New York: Agricultural Development Council, 1972).

[14] Zyuro Kudo, "Implications of Farm Management Research for Government Mechanization Programs," and Torng-Chuang Wu," Government Policies Promoting Farm Mechanization," in Farm Mechanization in East Asia ed. Herman Southworth (New York:Agricultural Development Council, 1972).

[15] Labor used for rice production in Japan declined from 229 workdays to 141 workdays per hectare between 1956 and 1971. Ishikawa op. cit.

[16] Tsuchiya op. cit.

[17] This relationship is further elaborated in Chapter 2 of J.W. Mellor, The Economics of Agricultural Development (Ithaca, New York, Cornell U. Press, 1966).

[18] A non-technical disucssion of the input-output model is available in W. W. Leontief "The World Economy of the Year 2000," Scientific American 243:3, September 1980.

[19] C.S. Ahammed and R.W. Herdt, "A General Equilibrium Analysis of the Effects of Rice Farm Mechanization in the Philippines," prepared for the Conference on the Economic Consequences of Small Rice Farm Mechanization," IRRI, Los Baños, September 1981.

[20] P.F. Moya, "Benefit Cost Analysis of the Different Types of Irrigation Systems in Central Luzon, Philippines," paper prepared for A/D/C Workshop on Investment Decisions to Further Develop and Make Use of Southeast Asia's Irrigation Resources," IRRI Ag. Econ. Dept. Paper 81-11.

[21] H.P. Binswanger, The Economics of Tractor Use in South Asia, (A/D/C and ICRISAT, New York 1978).

[22] J.B. Duff, "Mechanization and Use of Modern Rice Varieties," in Economic Consequences of the New Rice Technology, IRRI, Los Baños, Philippines, 1978.

[23] FAO, 1975, "Summary Report of Meeting of Experts on the Effects of Mechanization on Production and Employment," in Effects of Mechanization on Production and Employment, (Food and Agricultural Organization of the United Nations, Rome).

[24] S.P. Pudasaini, "Farm Mechanization, Employment and Income in Nepal," IRRI Research Paper Series 38, August 1979.

[25] A.S. Bagyo, "The Impact of Mechanization on Production and Employment in Rice Areas of West Java," M.S. Thesis, UP Los Baños, August 1981.

[26] Examples from the Philippines include F. King, "Evaluation of the CB:IBRD agricultural credit program in the Philippines," (IBRD, Washington, mimeograph, 1974); R. Barker, S.S. Johnson, N. Alviar and N. Orcino, "Comparative economic analysis of farm data on use of carabao and tractors in lowland rice farming," paper given at the Farm Management Seminar with Focus on Mechanization: sponsored by the Institute of Small-scale Industries, Manila, 1969. A very careful study of comparable farms within villages in West Godavari, India found no yield differences between bullock and tractor operated farms: V. Abraham, "Yield and Employment Effects of Tractor Use in Agriculture: A Case Study of Bullock and Tractor Using Farms in West Godavari District," PhD thesis submitted to Andhra University, 1976.

[27] Pudasaini op.cit.

[28] Y. Hayami and R.W. Herdt, "Market Price Effects of Technological Change on Income Distribution on Semisubsistence Agriculture," American Journal of Agricultural Economics, May 1977.

[29] Yujiro Hayami in association with M. Kikuchi, P. Moya, L.M. Bambo, and E.B. Marciano, Anatomy of a Peasant Economy, IRRI, Los Baños, 1978.

[30] Inderjit Singh, Small Farmers and the Landless in South Asia, World Bank Staff Working Paper No. 320, 1979.

[31] C. Gotsch, "Economics, Institutions and Employment Generation in Rural Areas," E.O. Edwards ed. Employment in Developing Nations (New York, Columbia U. Press, 1974).

[32] I haven't tracked down the Wolfe reference, but Griffin uses this, among other places in his essay "Rural Development: The Policy Options," which appears in the volume edited by E.O. Edwards that is cited in footnote 31.

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Table 1. Power tiller and tractor numbers, wage rates and rice prices, by country, 1971-75 average.

	Tillers per 1000 ha crop land	Wheel, crawler tractors per 1000 ha	Farm wage rate US$ per day	Farm wage rate kg rough rice per day	Farm price rough rice US$ per mt
South Asia					
India	*[a]	1.0	0.26	2.1	125
Pakistan	+[b]	1.6	0.39	3.3	119
Sri Lanka	0.1	6.1	0.42	2.6	161
Bangladesh	+	0.3	0.68	3.3	206
Southeast Asia					
Malaysia	0.4	2.3	2.53[c]	12.9[c]	195
Thailand	8.0[c]	1.1	0.59	7.9	75
Philippines	4.1[c]	1.0	0.34	3.1	109
Indonesia	+	0.5	0.71[c]	4.3[c]	167[c]
Burma	0.1	0.8	0.39	7.0	56
East Asia					
Japan	615	48.5	8.78	15.6	563
Taiwan	38	0.6	2.80	17.1	164
Korea	20	0.1	2.07	9.3	223
China	130[d]	4.2	n.a.	n.a.	n.a.

[a] No data available, but authors estimate there are less than 0.5 per 1000 ha.
[b] No statistical estimates available, authors estimate less than 0.05 per 1000 ha.
[c] Refers to 1976.
[d] Refers to 1978.

Sources: Tiller numbers from the IRRI Agricultural Engineering Department. Tractor numbers from FAO Production Yearbooks, except tiller numbers in Thailand and China - from Ishikawa (1981). Wage rates from Appendix Tables (time series) or World Rice Statistics (IRRI). Rice price from Appendix Tables (16.4); World price averaged $310/mt of rice equal to about $200/mt of paddy over the period 1971-75.

Table 2. Agricultural machinery in Japan (in thousands), 1950-1979.

Year	Power tiller		sprayers, dusters	Rice planting machines[a]	Threshers	Combine
	Walking type	Riding type				
1950	13		16		n.a.	
1955	63		88		1,737	
1960	514		407		2,458	
1965	2,490	19	837		3,048[b]	
1971	3,201	267	2,400	46	3,279[c]	84
1976	3,183	721	2,899	1,046	n.a.	428
1979	3,168	1,096	2,618	1,601	n.a.	747

[a] Power machines. For 1971 through 1973 about 30,000 hand transplanting machines reported, but their number remained constant over the period and none were reported thereafter.

[b] Refers to 1964.

[c] Refers to 1968.

Sources: for all data except threshers: 1950-55 - Institute of Developing Economies, One Hundred Years of Agricultural Statistics in Japan, 1969; 1956-73 - M. Kikuchi, K. Moshida, Y. Hayami, "Rice Statistics in Japan," IRRI, 1975; 1976-79 - Ministry of Agriculture, Forestry and Fisheries, Government of Japan, Monthly Statistics of Agriculture, Forestry and Fisheries. For power threshers: H. F. McColly, "Agricultural Mechanization in Developing Countries, ed., M. Esmay and C. Hall (Tokyo, Shin-Norinsha and Co., Ltd., 1973).

Table 3. Farm level rice prices and wage rates during comparable periods of agricultural mechanization, Japan, Korea and Taiwan.

State of mechanization		Period	Farm prices in domestic currency		Real wage kg paddy per day	Prices in US$		
			Rice/mt (paddy)	Wages/ day		Rice/mt b/	Wages/ day	World rice price
				Japan				
Initial	Introduction	pre 1950	na	na	na	na	na	na
Early	2.5 tillers/1000 ha	1950-51	73,000	250	3.4	311	0.70	na
Take-off	20 tillers/1000 ha	1956	77,000	363	4.7	328	1.00	134
Full	100 tiller/1000 ha	1961	77,000	530	6.9	327	1.47	137
				Korea				
Initial	Introduction	1961	14,630	106	7.2	173	0.85	154
Early	2.5 tillers/1000 ha	1968	39,510	381	9.6	216	1.36	201
Take-off	20 tillers/1000 ha	1972	87,680	803	9.2	338	2.02	148
Full	100 tillers/1000 ha	1978	17,600	2900	16.5	559	5.99	367
				Taiwan				
Initial	Introduction	1955-56	1,600	na	na	86	na	134
Early	2.5 tillers/1000 ha	1961 a/	3,595	35	9.7	98	0.88	137
Take-off	20 tillers/1000 ha	1970	4,734	71	10.1	176	1.77	143
Full	100 tillers/1000 ha c/	1978	9,080	254	27.9	376	7.06	367

a/ Taiwan passed 2.5 tillers/1000 ha in 1958, but wage data are not available for that year. 1961 is the first year for which they are available.

b/ Paddy price shown in 1st col, converted to rice @ .65, converted to US$ at official exchange rate.

c/ Taiwan had 70 tillers/1000 ha in 1978, the year for which data are shown. By 1979 or 1980, it had undoubtedly surpassed 100 tillers/1000 ha.

Table 4. Growth rates of total labor force, non-agricultural portion and resulting residual rate of growth in agricultural labor force, Asian countries, 1970-2000.

	Growth rate of labor force		Growth rate of non-ag. L.F.* 1970-75	% of L.F. in non-ag. 1977	Resulting calculated growth in ag. labor force	
	1970-77	1977-2000			1970-75	1977-2000
Thailand	2.5	2.3	3.5	23	2.20	1.94
Pakistan	2.4	2.8	4.1	42	1.17	1.86
Philippines	2.1	2.6	3.5	49	0.75	1.74
Bangladesh	2.3	2.7	6.3	22	1.17	1.68
Burma	1.4	1.9	3.8	45	-0.56	1.46
India	1.7	1.9	3.1	27	1.18	1.46
Indonesia	2.0	1.9	3.3	40	1.13	0.97
Sri Lanka	2.1	2.2	3.7	46	0.74	0.92
Malaysia	3.6	3.0	4.8	56	2.07	0.71
Korea	2.9	1.9	5.4	55	-0.16	-2.38
Taiwan	1.9	1.6	4.4	66	-2.95	-3.84
Japan	1.3	0.8	2.4	86	-5.46	-9.03

*Growth rate in urban population used as a proxy.

Source: calculated from data in IBRD, World Development Project Report, 1979.

Table 5. Classification of variables that may contribute to the change in net social benefits generated from the introduction of mechanical technology in rice production.

Variable	Change in variable		Likely impact on NSB of overlooking change		
	Generally recognized	Often overlooked	Large	Moderate	Small
P_r : price of rice		x	x		
P_p : price of other crops		x			x
A_r : area of rice	x		x		
Y_r : yield of rice	x			x	x
A_p : area of other crops		x			x
Y_p : yield of other crops		x			x
C_r : rice cropping intensity	x			x	x
C_p : non-rice cropping intensity		x			x
P_l : market price of labor (wage)		x		x	
D_l : shadow minus market wage		x	x		
P_k : market price of capital (interest)		x		x	
D_k : shadow minus market interest		x	x		
P_t : market price of land (rent)		x			x
D_t : shadow minus market rent		x			x
L_r : labor used in rice production	x		x		
K_r : capital used in rice production	x		x		
T_r : land used in rice production	x		x		
L_p : labor used in non-rice		x		x	
K_p : capital used in non-rice		x		x	
T_p : land used in non-rice		x		x	

Table 6. Summary of studies on the impact of mechanized land preparation on cropping intensity in rice based systems, Asia.

Study	Area	Comparison	Cropping intensity effect	
King, 1974	Central Luzon, Philippines	Carabao vs Power tillers	1.03 +5%	(Poor irrigation)
King, 1974	Central Luzon, Philippines	Carabao vs Power tillers	1.70 +2%	(Good irrigation)
IRRI, 1980	Central Luzon, Philippines	Carabao vs Tractors	1.37 +44%	(Irrigated)
IRRI, 1980	Central Luzon, Philippines	Carabao vs Tractors	1.00 0	(Rainfed)
Pudasaini, 1979	Bara District, Nepal	Animal vs Tractors[a]	1.45 +14%	
Pudasaini, 1979	Bara District, Nepal	Pumpset vs Tractors and pumpsets	1.55 +12%	
NCAER, 1977	South, East India	Bullocks vs Power tillers	1.41 +2%	
Ahmed, 1975	Bangladesh	Bullocks vs Power tillers & tractors	1.70 +10%	
Narayana, 1977	Andhra Pradesh, India	Bullocks vs Tractors	1.04 +9%	
Consequences Team 1981	South Sulawesi, Indonesia	Before vs after tractor	1.83 -2%	(Rainfed sub-sample)
Consequences Team 1981	South Sulawesi, Indonesia	Before vs after tractor	1.92 -2%	(Irrigated sub-sample)
Bagyo, 1981	West Java, Indonesia	Manual vs Tractor	1.95 -11%	
Bagyo, 1981	West Java, Indonesia	Animal vs Tractor	1.93 -10%	

[a] Combined tractor owning and tractor hiring farms.

Table 7. Summary of studies on the impact of mechanized threshing on cropping intensity in rice-based systems, Asia.

Study	Area	Comparison	Cropping intensity effect	
Juarez, 1979	Iloilo, Philippines	Hand vs. power threshing	1.68 +13%	(Irrigated)
Juarez, 1979	Iloilo, Philippines	Hand vs. power threshing	1.55 +4%	(Rainfed)
Juarez, 1979	Laguna, Philippines	Hand vs. power threshing	1.43 +22%	
IRRI, 1980	Central Luzon, Philippines	Hand vs. power threshing	1.78 -23%	(Irrigated)

Table 8. Number of parcels on which surveyed farmers grew one or two crops per year with various combinations of land preparation and threshing techniques, Central Luzon, wet season 1979.

Land preparation	Crops per year	Number of parcels reporting			
		Manual threshing	Large mechanical thresher	Small mechanical thresher	Total
Tractor	1	0	0	0	0
	2	42	0	10	52
Tractor and animal	1	26	15	7	48
	2	34	4	7	45
Animal	1	7	33	14	54
	2	8	5	6	19
Total	1	33	48	21	102
	2	84	9	23	116

Table 9. Labor and fuel used in experiments on five alternative land preparation methods for rice production (average of 4 soil types, Philippines, 1973 wet season).

Tillage treatment					
Primary tillage	Secondary tillage	Labor (hr/ha)	Fuel (lt/ha)	Weeds (g/.2m^2)	Yield (t/ha)
64 hp tractor	carabao	45	20	16.7	3.61
14 hp tiller	carabao	49	15	12.3	3.56
7 hp tiller	7 hp tiller	29	36	11.0	3.81
carabao	7 hp tiller	56	26	14.4	3.60
carabao	carabao	81	0	17.9	3.60

Source: Duff 1978.

Table 10. Yield of first crop rice (t/ha) reported by record keeping farmers using two sources of land preparation power, two provinces, Philippines.

Location	Water control	Power source	Yield (kg/ha)				
			1976-77	1977-78	1978-79	1979-80	Average
Iloilo	Rainfed	Carabao	2.9	3.1	2.5	2.4	2.7
		Tractor	4.3	1.6	3.7	2.9	3.1
	Irrigated	Carabao	3.4	3.7	3.7	3.7	3.6
		Tractor	n.a.	3.4	4.6	2.5	3.5
Pangasinan	Rainfed	Carabao	1.9	1.5	n.a.	n.a.	1.7
		Tractor	n.a.	n.a.	n.a.	n.a.	n.a.
	Irrigated	Carabao	3.1	3.6	3.0	n.a.	3.2
		Tractor	2.9	3.9	3.8	n.a.	3.5

Table 11. Average "turnaround" time between harvest of first rice crop and planting of second rice crop on farm record keeping cooperators, by land preparation power source, two provinces, Philippines.

Location	Water control	Power source	Number of weeks				
			1976-77	1977-78	1978-79	1979-80	Average
Iloilo	Rainfed	Carabao	1.9	1.2	1.2	2.1	1.6
		Tractor	3.3	3.0	0.3	4.2	2.7
Iloilo	Irrigated	Carabao	2.6	3.4	1.9	2.8	2.7
		Tractor	n.a.	4.1	2.7	5.3	4.0
Pangasinan	Irrigated	Carabao	0.2	1.4	0.5	n.a.	0.7
		Tractor	3.0	1.8	3.3	n.a.	2.7

Table 12. Average monthly net income and consumption levels ($/household/mo) of landless workers and rice farmers, sixteen households, Abangay, Iloilo, second season, 1977-78.

	Young LWs (n=3)	Older LWs (N=5)	Small farmers (N=4)	Medium farmers (N=4)
Gross income	36.40	51.73	106.00	149.73
Own rice farm	0	0	51.33	97.83
Harvest share	24.67	29.17	1.33	0.50
Cash wages	5.17	8.17	0.17	0.17
Livestock sales	5.00	7.33	25.67	20.83
Non-farm income	1.67	6.33	0.33	2.33
Machine (thresher) rentals	0	0	27.33	23.83
Production expenses	0	0	36.00	65.20
Net income	36.26	50.00	70.00	84.53
Returns on machinery investments	0	0	25.06	25.06
Consumption expenses	32.53	42.40	48.80	60.93
% spent on rice	42	39	33	27

Source: A. Ledesma.

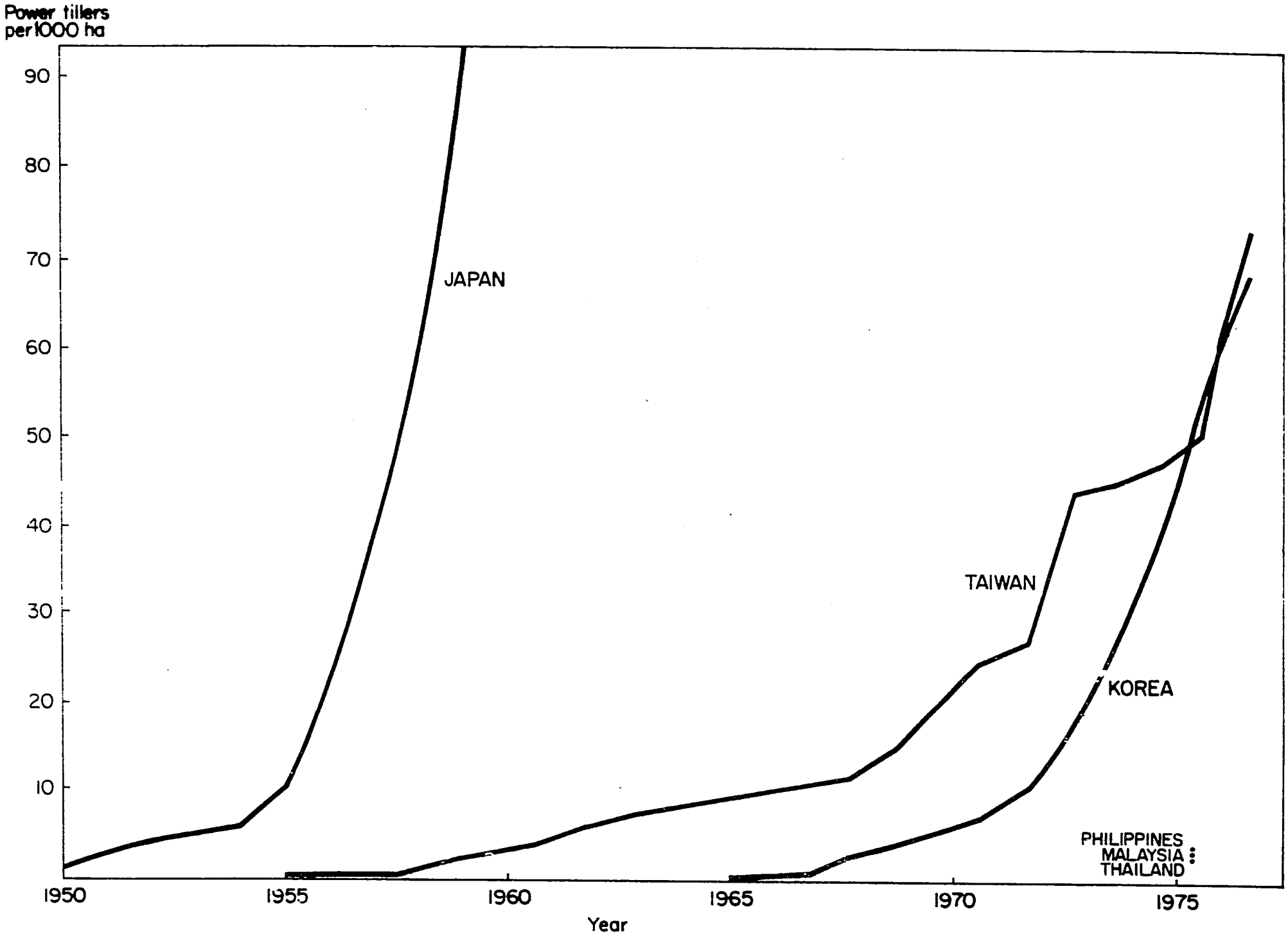


Figure 1. Growth in power tillers over time by selected countries.

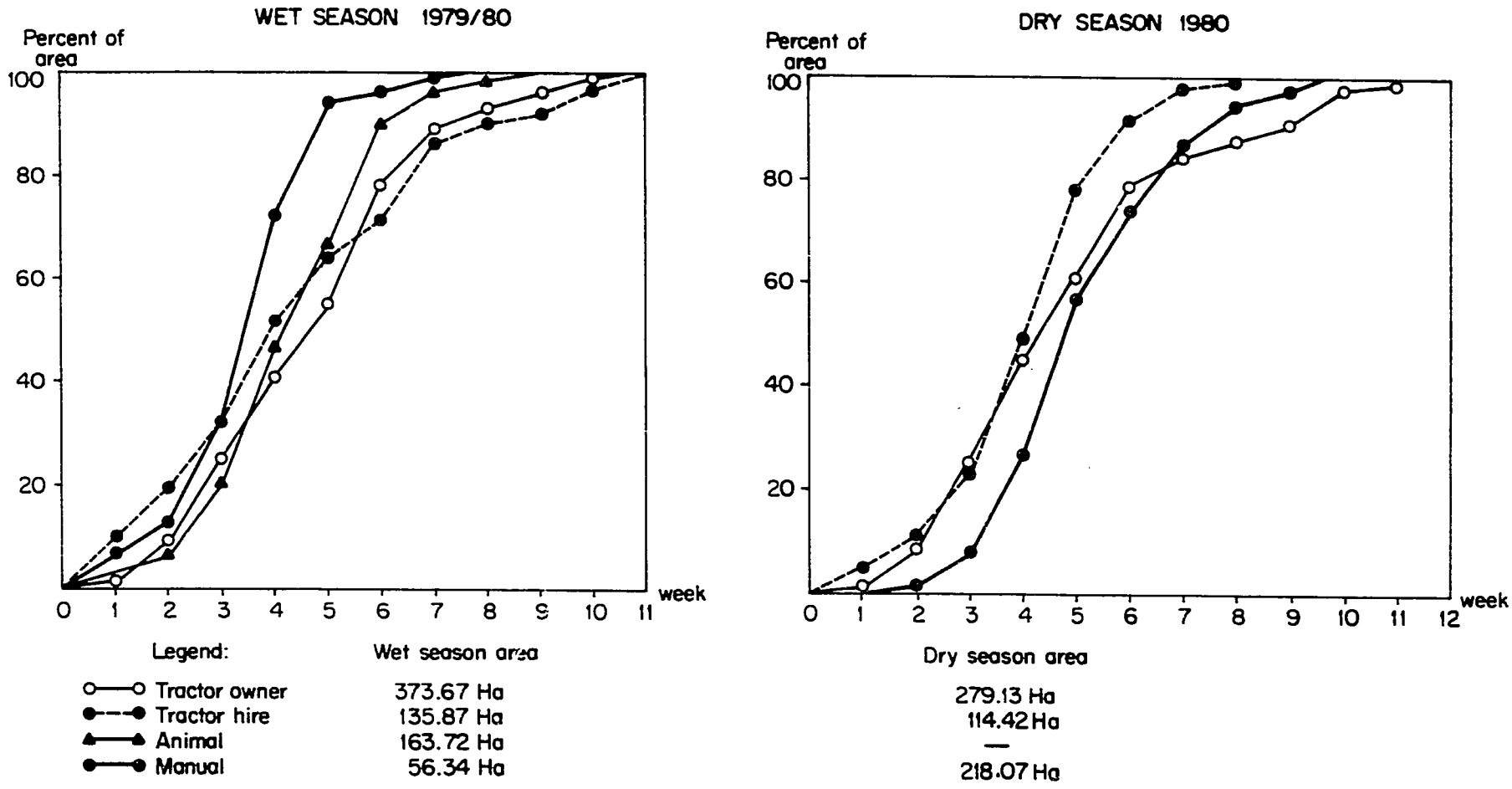
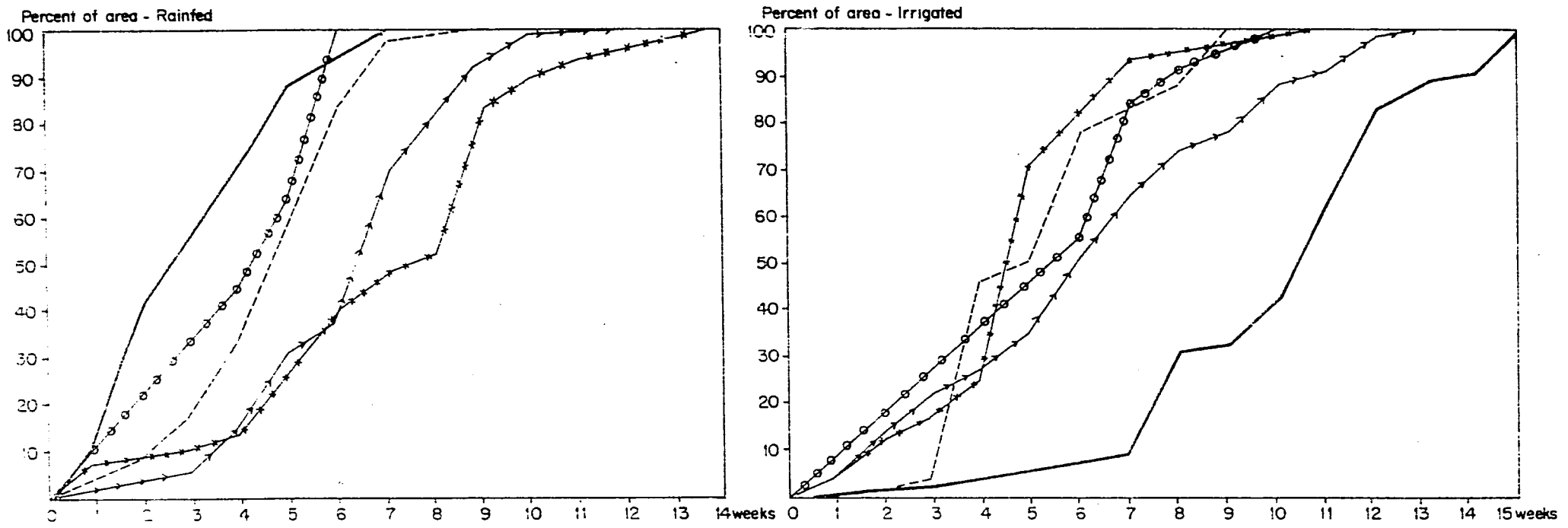


Figure 2. Cumulative frequency distribution of land preparation time for sample cooperations land. Subang and Indramayu Districts, West Java 1979-80.
Source: Consequences research team (1980)



LEGEND

- Man (M)
- Animal (A)
- Man + animal (MA)
- Man + tractor (MT)
- Man + animal + tractor (MAT/AT) or animal + tractor

Rainfed area (ha)	
M	3.37
A	50.93
MA	22.39
MT	2.65
MAT/AT	47.02

Irrigated area (ha)	
M	11.24
A	18.73
MA	21.10
MT	5.74
MAT/AT	61.59

Figure 3. Cumulative frequency distribution of land preparation time for sample cooperators land in Sindrap and Pinrang District. SOUTH SULAWESI, Wet season 1979.
Source: Consequences research team (1980)

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