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THE CONSEQUENCES OF SMALL RICE FARM MECHANIZATION PROJECT

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THE MECHANIZATION OF SMALL RICE FARMS IN ASIA

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By

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The International Rice Research Institute

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by

Bart Duff and P. Moran Kaiser**

INTRODUCTION

During the past two decades there has been a constant race to maintain a balance between food supply and demand in the rice producing countries of Asia. Rapid population growth combined with modest increases in per capita income have pushed consumption requirements for rice, the primary source of calories and protein upward at a rate exceeding 2% per year. With the exception of Japan, there has been an increasing per capita demand for rice in all countries of the region. In the past 10 years, we have also witnessed an unprecedented rise in the cost of energy which has added to inflationary pressures in most economies, particularly those such as Thailand, Bangladesh, Sri Lanka and the Philippines which have few well developed petroleum resources of their own. The rising prices of both rice and inputs such as fertilizer, water, chemicals and power have impacted most markedly on the lower income groups within these countries. These groups spend a higher proportion of their incomes on rice and suffer most when rice prices increase as a result of higher production costs.

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There has been a positive response throughout the region to meet the challenge presented by this continuing crisis. Greatly accelerated investments in irrigation and infrastructure coupled with expanded research to develop and extend packages of modern rice varieties and complementary inputs have kept supply in equilibrium with demand for most years. During the past five years, however, it has become increasingly apparent that the spread of the new rice technology is slowing down. It has been estimated that three-fourths of the rice producers in Asia have been left untouched by the modern technology, particularly those dependent on rainfall or affected by problem soils and lack of control over water supplies.

In this paper, we are concerned with the growth and impact of agricultural machinery on rice production. The report is composed of seven sections. The first briefly reviews the current status of economic growth in the region and the associated changes in the level and composition of the rural labor force. The second and third sections present estimates of the present level and costs of mechanization. The fourth section deals with the relationship between use of agricultural engineering technologies and other improved inputs. The employment issue is touched on in the fifth section. Patterns of local manufacture of farm equipment are examined in the sixth and the final section presents a listing of priorities for potential agricultural engineering developments in the next decade.

Economic Development and the Expanding Labor Force

There has been measurable economic growth in most Asian economies, although the figures shown in Table 1 mask the recent impact which inflation has had on increases in Gross National Product and per capita incomes. Agricultural productivity has keep pace with overall growth and increases in population for all but a few countries. It is projected that rice production will have to increase at an annual average rate of 3.6% in Asia if supply is to keep pace with demand (Herdt, 1981a). If supply falls behind increases in demand, the poorest segments of the population will suffer most. These people spent the highest proportion of their incomes on rice and will be able to purchase even less if excess demand increases the rice price. With an estimated 600 million persons already subsisting at inadequate consumption levels in the 1970s, the failure of rice production to meet anticipated increases in demand at constant prices will push an additional 100 million into this category by 1970. A 1% annual increase in the rice price will add 50 million more to this figure (Herdt, 1981a).

Japan, Korea and the Republic of China exhibit rapidly declining labor force participation in the agricultural sector. This is evidence of extensive growth in the nonagricultural sectors which has increased the nonfarm demand for labor. In these instances, the substitution of mechanical for human and animal power is clear solution to the problem of maintaining agricultural production with less labor. It has also been highly complementary to the sustained growth of agricultural output.

All other countries have much larger proportions of their labor in agriculture and must anticipate an absolute increase in the numbers of persons employed in this sector over the remainder of this century. Clearly in the latter case, the use of machinery in agriculture must have as a primary goal augmentation of scarce resources such as land, water and purchased inputs rather than a net substitution of machines for labor.

Increases in rice production which have occurred during the past decade may be attributed to two major sources -- expansion in land producing rice and increases yields. Area expansion results from increases in the cultivated area and multiple cropping on existing land, primarily the result of investments in new and improved irrigation systems which permit cropping during the dry season. Higher levels of fertilizer inputs, improved irrigation and wider use of modern varieties account for higher yields. Table 2 indicates that approximately 40% of the increases in production during the 1970s result from an expansion in area while the remainder are attributable to higher yields. The picture is highly variable among countries, reflecting differential access to additional land, appropriate yield increasing technology and the availability of funds and research resources. Accordingly, each country also reflects differences in the type, degree and composition of mechanization which is employed.

An Inventory of Rice Mechanization in Asia

National data on the number, size, composition, distribution and use patterns of agricultural machinery are nearly impossible to identify and the degree of reliability for data which are accessible is usually low or of indeterminant quality. The figures presented in this section should, therefore be viewed with caution and interpreted as only orders of magnitude rather than as precise estimates.

The Asian Productivity Organization recently completed a regional survey of mechanization in which both cross-country and temporal comparisions are made (APO, 1981). Table 3 presents estimates of the labor and power used in rice production for eight countries. While these figures represent averages or regional approximations which conceal the wide variability which exists within countries, they do permit some useful observations. In the case of Japan, Korea and the Republic of China, labor use has been falling rapidly throughout the 1965-78 period. This reflects the increasing urbanization of these economies and a higher degree of mechanization. Animal power is essentially non-existent in Japanese rice production. Mechanical hours are also beginning to decline after a high of 170 in 1970, evidence of a move to larger machines which permit more rapid completion of work. It is striking that although Japanese rice production is one of the most highly mechanized in the world, there is still a higher level of labor input than for many other countries in the region. Small farms (see Table 5) combined with the

high support price for rice continues to make labor used in rice production highly profitable.

Labor use in the Philippines, India, Pakistan and Nepal has increased during the period, largely the result of using the modern rice varieties, although the rise has been partially mitigated by increasing use of mechanization, particularly for land preparation and threshing in the Philippines and Thailand. Thailand shows an increase in the number of machine hours, but with little change in unit labor requirements. Thailand has only recently begun to employ the more labor intensive modern rice varieties. The figures for India portray a local situation. Mechanization of rice production is not common in most of the major rice growing areas of the country, although it is common in the wheat growing regions of East and West Punjab. Mechanical land preparation and threshing are only recent innovations in the rice production systems of Pakistan.

Table 4 indicates the average density of selected machines. With the exception of the three most advanced countries, one can characterize most countries as being at an introductory or experimental stage of mechanization. This is more clearly shown in Table 5 by the low levels of mechanical power available expressed on a per hectare basis, although in some instances the estimates of machine power represent a high percentage of the total power available. The limitation of these figures is they do not provide an indication of the degree to which the stock of mechanical power is utilized, i.e. how many hp-hrs/ha/crop do machines contribute to the total power needs of agriculture. Nor do

they give an indication of who uses the machines. Larger farmers may depend almost exclusively on mechanical power with smaller farms relying on animal and human power. There are, however, a number of small micro surveys which indicate that machine services are being made available on a contract basis to a wide cross section of both large and small farming units (IRRI, 1978; Juarez, 1979; Monge, 1980; NCAER, 1980; Smith, 1979). These studies have regretably not been able to resolve the issues of the distributional or employment impact of mechanization on small farmers or landless laborers in these countries.

A crucial factor in decisions to invest in mechanized equipment is the initial cost. In Table 6, we present the unit cost and rankings for two types of machines used primarily for land preparation. Calculations using private costs indicate that Nepal and Pakistan sell 4-wheel tractors at a lower cost than Japan. Four countries sell 10-hp diesel power tillers for less than Japan, Korea and the Republic of China. While these costs may partially represent the higher level of sophistication embodied in the machines (power steering, hydraulic controls, etc.) as opposed to simple "bare bones" machines, there may also be a degree of hidden subsidy which is not expressed in the selling price. To carry the analysis further, we have converted the dollar cost (using the domestic paddy price) to the rice equivalent (kg/hp) which a farmer must pay to acquire the machine. This figure reflects the real costs and would be the key element entering the decision to acquire a machine. In this instance, the ranking of machine costs closely parallels the level of mechanical power available in each country.

It is helpful to examine the degree to which prices have changed in these countries over time. Table 7 presents a series of indices for the price of paddy received by farmers compared to prices paid for inputs. In Japan, Korea and the Republic of China, paddy prices have advanced more rapidly than the cost of machinery. Rural wages in the latter two countries have also shown a comparatively higher rate of increase than farm equipment. In most cases, fuel prices have risen more rapidly than either rice or other input costs, particularly during the past five years. This price increase is most evident in the cases of the Philippines, Pakistan and Thailand, countries which have few domestic petroleum resources. With the apparent exceptions of Korea, India and Nepal, the rise in the cost of fuel has not been compensated by a commensurate increase in the price of paddy. The price of draft animals has also risen substantially in a number of countries. While these indices should be accepted with caution, they are instructive in interpreting trends in machinery use for a number of the countries under review.

In contemporary developing nations improved water lifting devices have often been the initial major engineering device employed on a wide scale (where irrigated agriculture is possible). Examples from Pakistan, the Indian Punjab, Thailand and Vietnam indicate the very high return to investments in these innovations. Land preparation equipment and power threshers are also found in large numbers in many countries (APO, 1981' NAERC, 1980). The sequence in which macnines are introduced appears to follow a generally predictable pattern with energy intensive operations such as tillage, threshing, water pumping and grain processing being

mechanized initially and most intensively. The Japanese model shown in Fig. 1 appears to be closely paralleled by the Republic of Korea and Taiwan (Fig. 2), both using similar designs (to a great extent provided through joint ventures with Japanese multinational firms). It is only at a later stages as economic conditions increase labor wage rates and/or domestic policies or technology increase the value of the crop that engineering innovations designed to emulate human dexterity in tasks such as transplanting become increasingly important (Chancellor, 1978).

In the future, rapid changes in technology and economic conditions, urbanization and rising expectations may modify the sequence of innovation from the historical pattern of Japan, Korea and Taiwan.

Mechanization and Production

An accumulation of evidence in recent years has addressed the issue of mechanization's impact on output. Because most of these cases deal with rice production in countries where the land frontier is closed, our focus is confined to the intensity and yield effects of mechanization.

Intensity effects. The assertion that machinery induces increased cropping intensification does not appear to be supported by the information presented in Table 8. The studies cited deal with cross-sectional comparisons of traditional and mechanical techniques of land preparation. In most cases, there appears to have been care taken to ensure comparability between samples, although clearly farms in each category may

have differed from each other in characteristics other than the method of land preparation used. Inspite of this possible methodological limitation, there is a striking consistency in the lack of differences in cropping intensity between mechanized and non-mechanized pairings. A similar finding is illustrated in Table 9 when one compares the manual and mechanical threshing techniques. In Table-10, the growth in mechanical tillage equipment is compared with changes in the multiple cropping index (MCI). While there are clearly economic reasons associated with the decline in the MCI, increasing mechanization certainly was unable to sustain it at previous levels. A corollary issue is whether power tiller use was able to mitigate the decline in cropping intensity.

The evidence presented here is not conclusive. A major difficulty with such studies is that they are not specifically designed to address the intensity issue. Examination of changes in this component of production are best evaluated over time and at locations where machine use and density have established a mature equilibrium.

Yield effects. For wetland rice production, beyond a minimal level power input, there appears to be no significant yield advantage of mechanical over manual or animal methods of land preparation. The evidence from the 7 studies cited in Table 11 indicates that when adjustments are made for the level of fertilizer used, yield differences between mechanically and traditionally tilled fields become insignificant. An exception is the Tan and Wicks study which has consistently shown a significant difference.

Experimental data for a wide range of tillage technique developed by Orcino and Duff (1974) for irrigated and rainfed rice support the general conclusion reached by the surveys cited above.

In the case of tillage it appears to be the cost reducing nature of the mechanical technology which induces its adoption and use rather than output effects which manifest themselves through crop yield or intensity.

The data examining the impact of mechanical threshing is not as comprehensive as the studies dealing with tillage. In those cases where output has been monitored, there does appear to be a direct yield increase of 4 - 6% when compared with traditional threshing methods (Toquero et. al, 1976; Maranan, 1978). Upon closer inspection we find, however, the extra yield attributed to the thresher represents the same quantity of grain formerly "salvaged" by those people who gleaned the straw piles left by the manual threshing crew. In this case, the gain to the farmer is a loss to the gleaners; the latter generally representing a low income segment of the village community.

We must reiterate a cautionary note at this juncture. Our attention has dealt exclusively with machines for land preparation and threshing. It would be a mistake to generalize from these findings to conclude that mechanical technology is only cost reducing and has no quantitative effects. Mention was made earlier of the importance in many countries of more efficient water lifting devices in reaching current yield and intensity levels. Pest control equipment, grain drying and processing machines and minimum tillage tools all contribute directly to increased output.

The future may also see equipment which will reduce inorganic fertilizer requirements without sacrificing yields. Lastly, it is well recognized that the environmental, economic and technical conditions which make engineering innovations suitable are very location and time specific. It is conceivable that there may be sufficient intra-regional variation within a country to realize an output impact from mechanization in one location and not at others.

Mechanization and Employment

It was clear in examining the data from Japan, Korea and Taiwan that the principal motivation in substituting machines for animal and human labor was a rising rural wage induced by industrialization, urbanization and the structural transformation of these economies. There appears to be a different set of forces at work in the labor-surplus countries of the region. While private profitability is the driving force in decisions to invest in agricultural equipment at the farm level, the presence of highly skewed patterns of access to and ownership of the means of production (land, water, credit) poses the danger of inequitable distribution of the gains from increased agricultural productivity. There are many who voice concern that machines may further exacerbate an already precarious level of income for small farmers and landless laborers (Herdt, 1981b; Sisler, 1979).

The data available indicate that as mechanized land preparation is introduced, it is primarily family and animal labor which is replaced (Table 12). For other operations such as threshing, which in many

countries is traditionally performed by hired labor, there seems to be a much greater danger that these people will lose their jobs. In the absence of alternative employment opportunities, this can lead to a lower level of income. Survey work in the Philippines does support the contention that mechanical threshing reduces total labor requirements of which a substantial portion is hired (Table 13). While the relative proportion and the real wage per worker increase as a result of mechanical threshing, total mandays decreases. The net impact is a reduction in earnings by hired labor.

Private profitability provides the inducement to invest in the machines. It is not clear, however, whether the gap between the farmer's benefits and the laborer's losses truly reflects society's gain from use of the machine. The research by David (1982) and Supachat (1982) in evaluating the domestic resource costs of these innovations point to some distortions which have tended to subsidize the machines through special credit programs and (before 1978) subsidies on fuel in the Philippines. The degree and nature of these subsidies needs further evaluation.

Domestic Manufacture of Agricultural Equipment

The recent APO survey tends to confirm that most countries have moved rapidly in the past decade to internalize production of agricultural machinery. In some instances this has been a conscious effort on the part of planning agencies to maximize employment and provide backward linkages with the agricultural sector. In other cases, such

as Thailand, there seems to have been little government intervention in the establishment of the agricultural machinery manufacturing industry. It appeared as a consequence of the demand for supplemental farm power. An expanding farm area coupled with large farm size may have induced these developments in the early 1960s (Binswanger, 1982).

The high cost and inappropriate nature of existing machinery from the developed world was another factor which has conditioned the establishment of efforts to design and develop suitable low cost equipment for small rice farms. Most governments view these efforts with enthusiasm as they promote the development of small-scale manufacturing, enhance skills, provide employment in labor-intensive processes, reduce foreign exchange requirements and are seen as a means to decentralize industrial development. One of the most difficult problems facing countries in the region is the provision of gainful employment to those who move to large cities such as Manila, Jakarta, Lahore, New Delhi and Bangkok. This pattern of urbanization has created tremendous problems in the provision of services such as education, sanitation, law enforcement and housing. A solution suggested by some is to encourage small- and medium-scale industrial development in smaller regional cities (Hackenburg, 1980). These provide ready access to rural markets and would be better able to cope with problems induced by migration from the countryside.

A principal problem in encouraging regional or decentralized development is the identification of suitable industries which have a demand in the agricultural sector. Agricultural equipment of simple design appears to meet this need. The remaining constraint has been

provision of suitable designs which meet the technical and economic requirements of the small farmer.

There are many examples of industrial products which have emerged in response to a perceived demand in agriculture. The diesel engine and tubewell industry in Pakistan and the water pump and power tiller manufacturers in Thailand are excellent illustrations. In the Philippines, the hundreds of small companies making Jeepney bodies throughout the country also attest to the ability of local entrepreneurs (Cabanos, 1971). The Ford Motor Company's Fiera, an austere utility vehicle, represents a somewhat more formal attempt to maximize use of local resources while realizing the economies of mass production (Follosco, 1978).

For those responsible and concerned with the planning and implementation of efficient agricultural development strategies, a key question is "what pattern of mechanization results in sustained increases in production while concurrently providing equity and social justice in the distribution of benefits?" It should be apparent the answer will depend greatly on the economic, cultural and technical conditions inherent in each specific environment. These conditions will differ among countries and between regions within countries.

A general sequence of activities seems necessary (although not always sufficient). The following scenario is suggested by the experience of the Agricultural Engineering program at the International Rice Research Institute:

Sequence of Activities	Main Actors
1. Identification of needs	Interdisciplinary farmers engineers social scientists biological scientists research administrators policy planners
2. Conceptuatlization of suitable technology	Engineers
3. Transfer, adapt or development of technology	Engineers
4. Test and Evaluation	Engineers working with relevant interdisciplinary group
5. Industrial Extension of Technology	Engineers, manufacturers and policy makers
6. Farm level Extension	Manufacturers, extension personnel and policy makers

The system must be responsive to review and evaluation at any step in the sequence of activities. For example, the need for a technology may be identified at step one, but prove intractable to solution at the conceptual or development stages. A more difficult case would be the instance when a technology passes through steps one to four, but upon review it is felt if the resulting machine were released it would produce a potential net negative impact on incomes at the farm level.

With modifications reflecting local conditions, the system or variants has been implemented through industrial extension programs

working closely with local agencies in six Asian countries. After nearly 10 years of intensive effort, the result has been a significant increase in the number of local firms producing agricultural machinery utilized by a broad cross section of rice farmers. An additional benefit has been the demonstrated capacity of these firms to graudally assume and expand their participation in the R & D process. In a recent Philippine study, Mikkelsen (1981) reports that well over 40% of the firms participating in IRRI's industrial extension program were involved in formal "inventive" R & D. Only two of the 45 firms in the survey did no "innovative" (as contrasted with "inventive" work to improve the performance of the machine, to differentiate it from others being sold in the same market or to adapt it to the firm's manufacturing capabilities.

Priorities for Agricultural Engineers

We have referred repeatedly to the need to develop a conherent and comprehensive approach to the mechanization of small rice farms. We suggest the following as urgent topics for agricultural engineering research in the 1980s:

1. A clearer identification of engineering needs at the farm level with specific attention to local technical, economic, cultural and environmental conditions. Scarce research resources should be committed only to those design and development projects which potentially contribute a net positive benefit, weighing both the short and long run

Table 1. Cross-country comparison of growth in Gross National Product, Agricultural Production and Labor Force in Asia.

Country	GNP/Cap. 1979 (US$)	Growth of Real GNP 1971-80 (%)	Growth of Ag. Prod. 1971-80 (%)	Growth of Labor for 1970-80 (%)	Labor in Agric. 1960 (%)	Labor in Agric. 1979 (%)	Projected Growth Ag. L.F. 1977-2000
Japan	8718	5.5	1.2	1.3	33	13	-9.03
Republic of China	1650	2.3	2.3	2.3	--	22	-3.84
Republic of Korea	1500	3.9	3.9	2.8	66	36	-2.38
Malaysia	1370	4.0	5.0	2.6	63	51	.71
Philippines	600	6.1	4.1	2.4	61	47	1.74
Thailand	590	7.0	4.7	2.7	84	77	1.94
Indonesia	380	7.5	2.9	2.5	75	59	.97
Pakistan	270	4.5	3.0	2.6	61	57	1.86
Sri Lanka	230	4.0	2.0	2.0	56	51	.92
India	190	3.2	2.1	1.7	74	71	1.46
Burma	160	1.1	3.9	1.5	--	67	1.46
Nepal	130	2.2	1.5	2.1	95	93	--
Bangladesh	90	-0.1	1.9	3.3	87	74	1.68

Sources: As cited in Asian Productivity Organization 1981a, p. 5. Data for labor force in agriculture and country figures for Malaysia, Burma and Bangladesh from IBRD, World Development Report, 1981, pp. 134, 170-71. Porjected labor force growth rates from Herdt, 1981a.

Table 2. Growth rates of rice production, area and yield compared to growth rate in agricultural labor force, 1970-1978.

Country	Growth rate (%/year)					
	Rice production	Rice area	Rice yield	Agricultural labor force	Output per worker	Labor per hectare
			Mainly rice based agricultural sector			
Bangladesh	1.97	0.58	1.39	1.17	0.80	0.59
India	2.46	0.68	1.78	1.18	1.28	0.50
Burma (projected L.F.[a])	3.07	0.99	2.08	-.056	1.61[a]	0.47[a]
Indonesia	3.80	1.20	2.60	1.13	2.67	-0.07
Thailand	2.96	2.23	0.73	2.20	0.76	-0.03
Philippines	5.39	0.79	4.60	0.75	4.64	-0.04
			Other crops predominant in agricultural sector			
Pakistan (wheat)	4.95	4.76	0.19	1.17	3.78	-3.59
Sri Lanka (tea, spices)	4.99	4.78	0.21	0.74	4.25	-5.54
Malaysia (rubber, oil palm)	2.69	3.38	-0.69	2.07	0.62	-1.31
			Declining agricultural labor force countries			
Burma	3.07	0.99	2.08	-0.56	3.63	-1.55
Korea	4.37	0.53	3.84	-0.16	4.53	-0.69
Taiwan	0.40	-0.43	0.83	-2.95	3.35	-2.52
Japan	0.31	-1.00	1.31	-5.46	5.77	-4.46

Source: Rice growth rates calculated from USDA Foreign Agricultural Circular" Grains 79-20; other data from Table 1 or calculated from Table 1 and first 3 columns of this table.

[a] Uses of the projected (1977-2000) rate of growth in agricultural labor force rather than the 1970-75 because the latter actually registered a decline.

Table 3. Estimated inputs of human, animal and mechanical power in rice production in selected countries of Asia, 1980 (hrs.)

Country	1965	1970	1975	1978
Japan				
Human	1410	1178	815	694[a]
Animal	15	2	---	---
Mechanical	144	185	179	148[a]
Republic of China[b]				
Human	1088	985	778	601
Animal	122	103	51	36
Mechanical	40	56	84	98
Republic of Korea				
Human	1356	1284	1176	937
Animal	92	101	80	56
Mechanical	4	8	18	48
Philippines[c]				
Human	504	552	640	640[d]
Animal	200	136	136	136[d]
Mechanical	42	45	45	45[d]
Thailand[c]				
Human	490	480	470	462
Animal	170	165	160	146
Mechanical	10	15	20	30
India[e]				
Human	1218[f]	958	992	1285[a]
Animal	230[f]	247	221	125[a]
Mechanical	120[f]	na	na	113[a]
Pakistan				
Human	619	637	637	637[a]
Animal	312	308	284	128[a]
Mechanical	na	neg.	2	6[a]
Nepal				
Human	1200[f]	na	na	1448
Animal	312[f]	na	na	304
Mechanical	neg.[f]	na	na	2

Source: APO, 1981a.

Notes: a-1979, b-refers to first season crop only, c- refers to wet season crop, d-1977, e-average of Tamil Nadu and Orissa, f-1960.

Table 4. Estimated inventory of selected agricultural machinery per 100 hectares of arable land.

Country	Water pumps	Power tiller	4-wheel tractor	Hand sprayer	Hand thresher	Power thresher	Reaper	Combine
Japan	---	50.4	26.9	---	---	55.5	29.6	16.2
Republic of China	19.3	7.3	0.3	34.4	17.9	6.0	0.6	1.0
Republic of Korea	9.0	11.4	0.1	41.3	13.2	9.7	0.6	0.02
Philippines	1.1	0.9	0.3	3.8	0.03	0.16	---	---
Thailand	2.0	1.4	0.3	5.9	---	0.03	---	---
Indonesia	0.03	0.02	0.01	2.1	0.01	0.009	---	---
Pakistan	0.89	---	0.38	0.08	---	0.08	---	---
Sri Lanka	1.1	1.0	1.8	1.5	0.01	0.05	---	---
India	0.24[a]	0.01	0.23	0.49	---- 0.49	---	---	---
Nepal	0.39	0.02	0.11	0.12	0.80	0.01	---	---

Source: APO, 1981a. IRRI, 1978. Palacpac, 1980.

Note: Dashed lines indicate data not available or quantity used negligible. Statistics cover years from 1978-1980.

[a] Includes simple water lifting devices such as Persian wheels.

Table 5. Estimated farm power available by source in selected countries of Asia.

Country	Animal power	Mechanical power	Total	Animal power	Mechanical power	Ave. farm size (has)
	----------hp/ha		----------	---------%	----------	
Japan	----	11.0	11.0	--	100	1.17[a]
Republic of China	0.06	2.14	2.2	3	97	1.04
Republic of Korea[b]	0.42	1.30	1.72	25	75	1.02
Philippines	0.46	0.33	0.79	58	42	3.6[c]
Thailand	0.15	0.16	0.31	48	52	4.1
Indonesia	0.16	0.03	0.19	84	16	0.99[d]
Pakistan[f]	0.13	0.36	0.49	27	73	5.26[g]
Sri Lanka[b]	0.15	0.28	0.44	36	64	1.23[d]
India[e]	0.26	0.22	0.48	54	46	1.95[e]
Nepal[e]	1.14	0.08	1.22	96	4	1.20[c]

Source: APO, 1981a, IRRI, 1978. Palacpac A. 1980.

Notes: a-1980, b-1979, c-1971, d-1973, e-1977, f-1976, g-1972.

Table 6. Ranking the nominal and real costs of 65HP diesel tractors and 10HP power tillers in selected countries of Asia, 1980.

Country	Nominal cost --65hp ($/hp)	rank	--10hp-- ($/hp)	rank	Real cost[a] --65hp-- (kg/hp)	rank	--10hp-- (kg/hp)	rank	Power available hp/ha	rank
Japan	251	6	310	9	226	1	279	1	11.0	1
Republic of China	177	3	220	5	421	2	523	3	2.14	2
Republic of Korea	---	-	201	4	---	-	402	2	1.3	3
Malaysia	346	7	264	7	1784	7	1360	7	na	-
Philippines	375	8	184	3	1932	8	948	5	.33	5
Thailand	246	5	120	1	1607	5	784	4	.16	8
Indonesia	413	9	440	11	1966	9	2095	9	.03	10
Pakistan	172	2	---	-	1387	4	---	-	.36	4
Sri Lanka	197	4	161	2	1728	6	1150	6	.28	6
Burma	na	-	242	6	na	-	3967	11	na	-
Nepal	128	1	316	10	1040	3	2569	10	.08	9
Bangladesh	na	-	300	8	na	-	1758	8	na	-

Source: IRRI Country surveys of 1977 and 1981. APO, 1981a. Rice price data from Palacpac, 1980. World Rice Statistics.

Notes: [a]real costs are calculated by dividing the nonimal cost of the machine by the per kilogram farm gate price of rough rice.

Table 7. Price Indices for paddy and farm inputs in selected countries of Asia (1975=100).

Country	Paddy price	Farm machinery	Fuel	Rural wages	Draft animals
Japan					
1965	42	57	47	---	---
1970	53	62	50	---	---
1975	100	100	100	100	---
1979	114	110	138	113	---
Republic of China					
1965	37	57	67	---	---
1970	43	58	67	---	---
1975	100	100	100	100	100
1979	139	---	167	175	163
Republic of Korea					
1965	17	27	21	---	---
1970	33	45	25	---	---
1975	100	100	100	100	100
1979	201	158	110	385	194
Malysia					
1976	100	100	---	100	100
1980	93	150	---	235	118
Philippines					
1965	33	30	19	---	---
1970	38	51	25	---	---
1975	100	100	100	100	100
1979	105	150	279	122	198
Thailand					
1965	---	---	81	---	---
1970	44	44	81	---	---
1975	100	100	100	100	100
1979	113	277	280	148	334
Indonesia					
1965	---	---	---	---	---
1970	36	---	---	---	---
1975	100	---	---	100	100
1980	104	---	---	115	139
Pakistan					
1965	---	---	---	---	---
1970	42	38	86	---	---
1975	100	100	100	100	100
1977	116	114	237	115	120
India					
1965	65	40	33	---	---
1970	75	61	65	---	---
1975	100	100	100	100	100
1978	110	127	108	118	120
Nepal					
1965	65	40	33	---	---
1970	75	61	65	---	---
1975	100	100	100	100	100
1977	110	127	108	118	120

Source: Adjusted from APO, 1981a. Prices for draft animals from IRRI Country Surveys. Price data for Malaysia from Palacpac, 1980. World Rice Stat.

Table 8. 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 (poor irrigation) + 5%
King, 1974	Central Luzon, Philippines	Carabao vs power tillers	1.70 (good irrigation) + 2%
Deomampo and Torres, 1975	Central Luzon, Philippines	Before vs after tractors	1.68 + 7%
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 + 9%
Jabbar et.al. 1981	Bangladesh	Bullocks vs power tillers	1.63 + 9%
Alam, 1981	Bangladesh	Bullocks vs power tillers	1.19 + 2%
Narayana, 1977	Andhra Pradesh, India	Bullocks vs tractors	1.04 + 9%
Consequences Team, 1981	South Sulawesi Indonesia	Before vs after tractor	1.83 (rainfed sub-sample) - 2%
Consequences Team, 1981	South Sulawesi Indonesia	Before vs after tractor	1.92 (irrigated sub-sample) - 2%
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.

Source: See Reference.

Table 9. 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 (irrigated) + 13%
Juarez, 1979	Iloilo, Philippines	Hand vs. power threshing	1.55 (rainfed) + 4%
Juarez, 1979	Laguna, Philippines	Hand vs. power threshing	1.43 + 22%
Cordova et.al. 1981	Central Luzon, Philippines	Hand vs. power threshing	1.78 (irrigated) - 23%

Source: See Reference.

Table 10. Number of power tillers per 1000 ha paddy land and multiple cropping indices in three areas of Asia, 1950-1980.[a]

Years[b]	Japan		South Korea		Taiwan, China	
	Tillers/ 1000 ha	MCI	Tillers/ 1000 ha	MCI	Tillers/ 1000 ha	MCI
1951-55	8.2	127	0	n.a.	0	171
1956-60	58.9	135	0	141	1.8	180
1961-65	423.6	128	0.5	145	11.5	187
1966-70	880.9	117	5.4	142	25.9	186
1971-75	1294.1	103	37.4	138	47.0[d]	178
1976-80	1592.0	103	139.4	125[c]	70.9[e]	175[d]

[a] Calculated as total harvested area divided by the arable land area.
[b] Average of years indicated.
[c] 1980. [d] 1976 [e] 1978.
Source: As cited in Jayasuriya, et al(1982).

Table 11. Summary of studies comparing rice yields on farms with animal or hand land preparation with farms using mechanical methods.

Study	Area	Comparison	Reported yield (t/ha)	Fertilizer (urea) (kg/ha)	Adjusted yield (t/ha)
Pudasaini	Nepal (without pumps)	Bullocks vs	1.7	16	1.7
		tractors	2.1	164	1.4
Pudasaini	Nepal (with pumps)	Bullocks vs	2.1	214	2.1
		tractors	2.3	264	2.1
Sinaga	West Java, Indonesia	Animal vs	4.9	323	4.9
	(wet, 1979/80)	tractors	4.9	323	4.9
Sinaga	West Java, Indonesia	Manual vs	3.8	285	3.8
	(3 seasons, 1979-80)	tractors	3.9	308	3.8
Sinaga	South Sulawesi, Indonesia	Animal vs	2.7	138	2.7
	(3 seasons, 1979-80)	tractors	2.9	227	2.5
Tan & Wicks	Nueva Ecija, Philippines	Carabao vs	2.6	89	2.6
	(wet, 1979)	tractors	4.0	129	3.8
Anuwat	Central Thailand	Bullock vs	2.6	32	2.6
	(irrig, transplanted)	tractor	2.8	48	2.6
Anuwat	Central Thailand	Bullock vs	0.2	3	0.2
	(rainfed, broadcast)	tractor	0.2	2	0.2
Alam	Bangladesh	Bullock vs	1.5	na	1.5
		power tiller	1.5	na	1.5
Deomampo	Central Luzon,	Before vs after	2.2	57	2.2
& Torres	Philippines	tractors & tillers	2.6	79	2.1
Antiporta	Philippines,	Animals vs	2.6	86	2.6
& Deomampo	8 provinces	tractors & tillers	2.8	117	2.5

Sources: See References.

Table 2. Labor inputs (m-days/ha) for rice production at four locations in Asia.

Site		Year/season	Irrigated				Rainfed			
			Manual	Animal	Partially mech.	Mech.	Manual	Animal	Partially mech.	Mech.
Philippines	No. obs.	1979 WS	-	46	94	54	-	77	46	1
	Family			29.7	6.2	4.6		30.7	18.6	53.3
	Hired			53.9	58.5	54.1		42.4	44.8	44.5
	Total			83.6	64.7	58.7		73.1	63.4	97.8
West Java	No. obs.	1979/80 WS	56	100		68				
	Family		30.3	20.8		4.0				
	Hired		144.2	131.3		119.6				
	Total		174.5	152.1		123.6				
South Sulawesi	No. obs.	1979 WS		82		76		84		48
	Family			54.1		28.2		56.6		45.5
	Hired			49.7		75.3		71.8		85.5
	Total			103.8		103.5		128.4		130.9

Source: IRRI Mechanization Consequences Project.

Table 13. Labor requirements per hectare for harvesting and threshing modern rice varieties before and after thresher adoption and use, Iloilo and Laguna, wet and dry seasons, 1978-79.

Thresher use/labor arrangement	Irrigated Iloilo			Rainfed Iloilo			Irrigated Laguna			
	H	T	H+T*	H	T	H+T	W*	H	T	H+T+W
	manday/hectare									
User: Before thresher use	16.6	26.0	42.6	17.1	19.1	36.2				
Hired [a]	15.3	24.4	39.7	17.1	19.1	36.2	-	14.1	19.8	33.9
Contractual [b]	20.5	31.4	51.9	-	-	-	21.9	24.5	20.8	67.2
After thresher use	17.0	1.4	18.4	15.5	0.9	16.4				
Hired	14.7	1.2	15.9	15.5	0.9	16.4	-	14.5	4.4	18.9
Contractual	22.4	1.8	24.2	-	-	-	21.9	25.0	4.8	51.7
Non-user:	18.0	26.0	44.0	17.6	24.4	42.0				
Hired	18.0	27.7	45.7	17.6	24.4	42.0	-	-	-	-
Contractual	-	-	-	-	-	-	21.9	35.8	16.0	73.7
Family	18.0	16.0	34.0	-	-	-		12.0	22.0	34.0

* H - Harvesting; T - Threshing; W - Weeding

[a] Hired refers to the "pasapar" system in Iloilo and the "rumble" system in Laguna.

[b] Contractual refers to the "pakyaw" system in Iloilo and the *gama* system in Laguna.

Source: The Economic and Institutional Impact of Mechanical Threshing in Iloilo and Laguna, F. Juarez and B. Duff, The Consequences of Small Rice Farm Mechanization Project Working Paper No. 1., Agricultural Engineering Department, IRRI, October 1979.

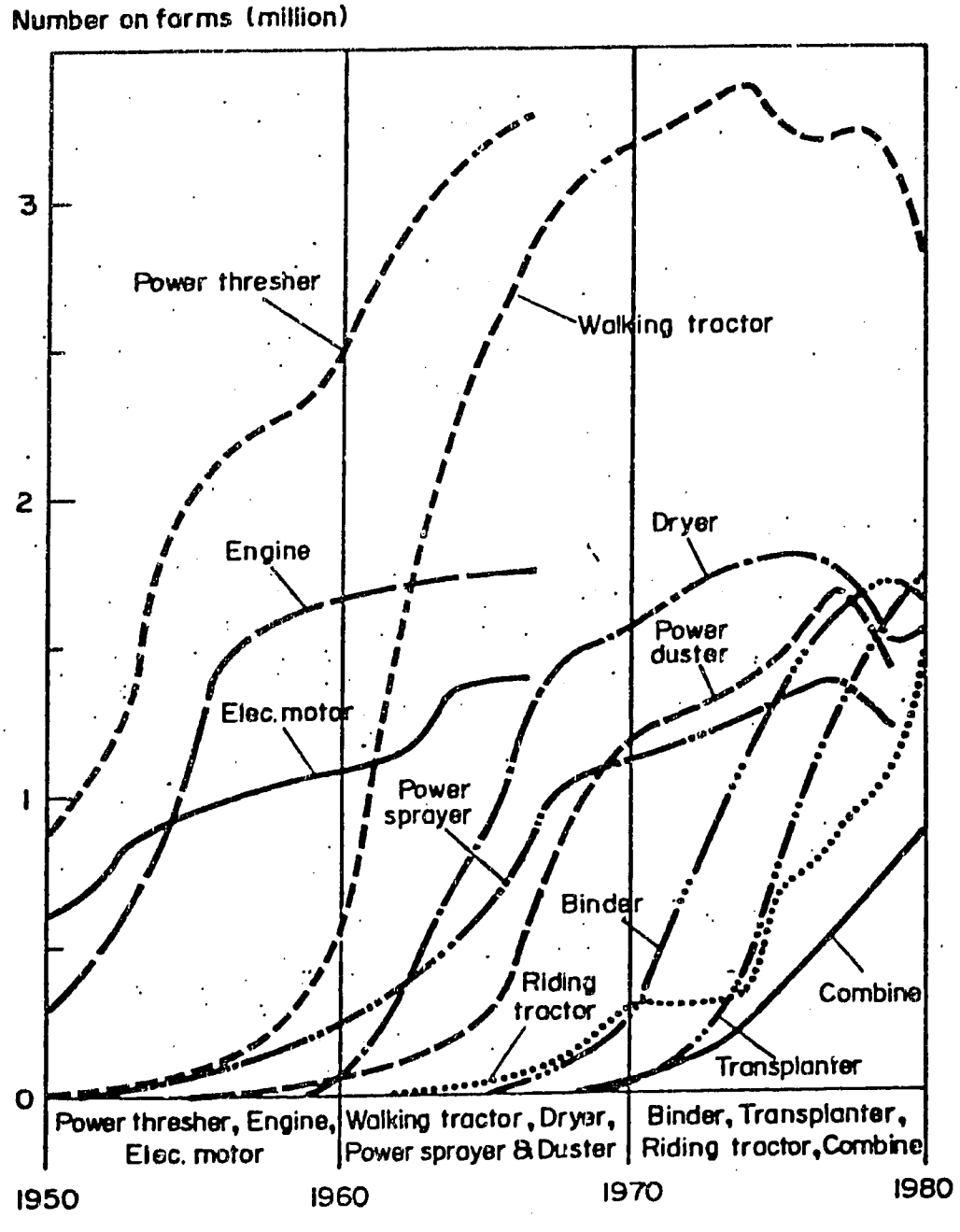

Fig. 1.. Development and diffussion of major farm machinery in Japan, 1950–1980. (Kisu, 1981).

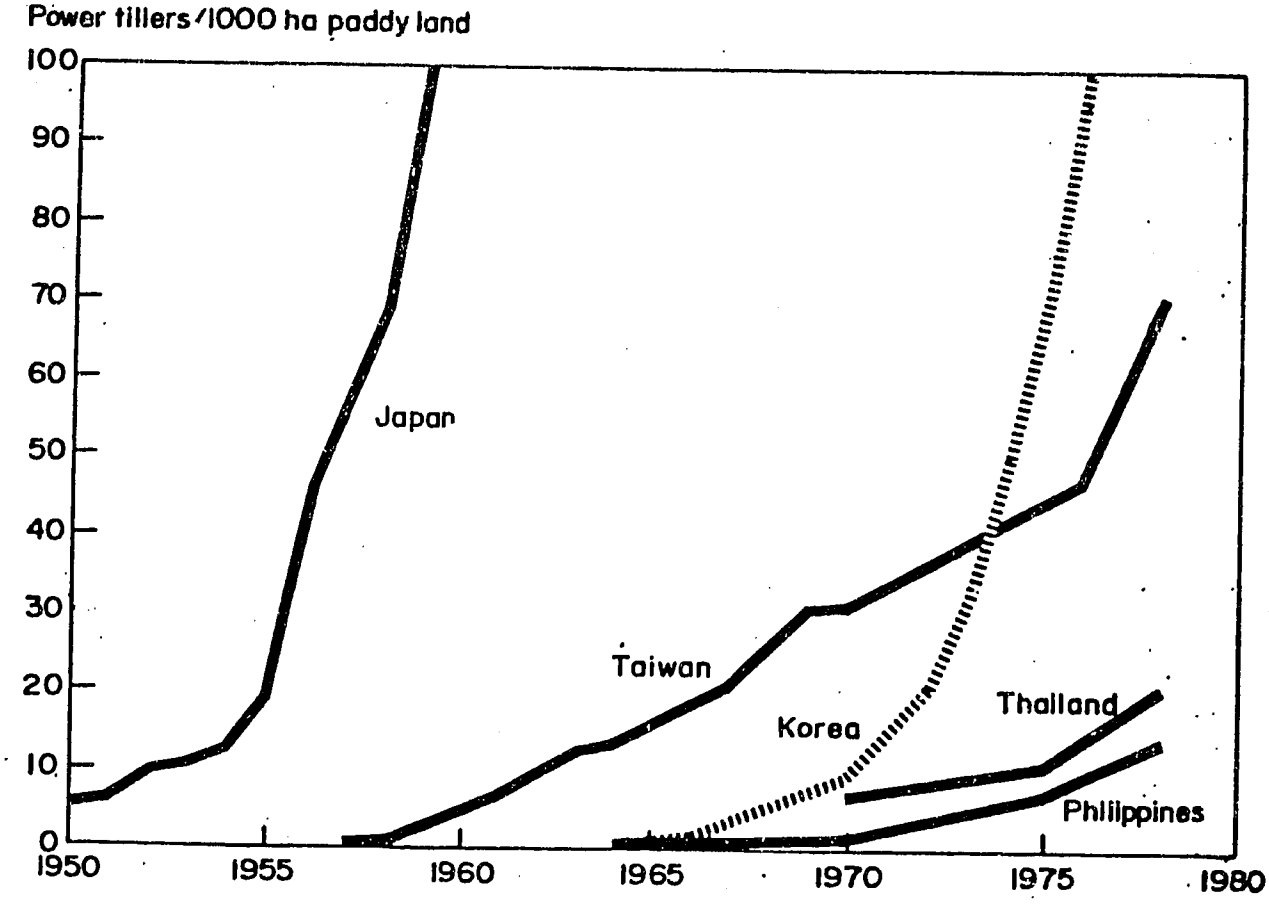

Fig. 2. Number of power tillers per 1000 ha paddy land. (Herdt, 1982)

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