ABSTRACT

The Composition, Growth and Impact of Small Farm Mechanization in Asia

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The paper reviews the experience of a number of Asian countries in the application of mechanization to small farm agriculture. Contrasts are provided between currently developed countries such as Japan, Korea and Taiwan, and those currently undergoing agricultural transformation. The evidence suggests a chronology in the adoption of mechanization with operations such as land preparation, threshing and water lifting being mechanized first. The evidence presented indicates that distortions in the pricing of agricultural equipment do exist in a number of countries.

Finally, the paper reviews a suggested strategy for the development of local manufacturing capabilities in the small farm machinery area.

ABSTRAK

Komposisi, Pertumbuhan, dan Dampak Mekanisasi Usahatani Kecil di Asia

Bart Duff

Makalah ini mengulas tentang pengalaman sejumlah negara di Asia dalam melaksanakan mekanisasi untuk usahatani kecil. Perbedaan antara kejadian di negara-negara maju seperti Jepang, Korea, dan Taiwan dibandingkan dengan negara-negara yang sedang mengalami pergeseran pola bertaninya. Hasil pengamatan menyarankan bahwa mekanisasi yang diadopsi pertama kali adalah pengolahan tanah, penggilingan gabah, dan pompa air. Distorsi harga peralatan pertanian sering terjadi di beberapa negara.

Akhirnya, makalah ini mengulas strategi yang disarankan untuk mengembangkan kemampuan industri lokal yang menangani alat-alat yang dibutuhkan usahatani kedil.

The Composition, Growth and Impact of Small Farm Mechanization in Asia

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During the past two decades rapid population growth combined with modest increases in per capita income have pushed consumption requirements for rice, the primary source of calories and protein in Asia, 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. This has added to inflationary pressures in most economies, particularly those (such as Thailand, Bangladesh and the Philippines) which have few well-developed petroleum resources of their own. The rising prices of both rice and such inputs as fertilizer, water, chemicals and power have impacted most markedly on the lower income groups within these countries. These groups spend a high proportion of their income on rice, and suffer most when rice prices increase as a result of higher production costs.

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.

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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 current 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 section. The final section presents a listing of generalization describing the observed sequence of introduction and the composition of machinery used in the Asian region.

Economic Development and the Expanding Labor Force

There has been measurable 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 kept 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 spend 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 1990. A 1% annual increase in the price will add 50 million more to this figure (Herdt, 1981a).

Japan, the Republic of Korea and Taiwan exhibit rapidly declining labor force participation in the agricultural sector (Table 2). 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 a 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.

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 (%/year)	Growth of ag. prod. 1971-80 (%/year)	Growth of labor force 1970-80 (%/year)	Labor in agric. (%) 1960	Labor in agric. (%) 1979	Projected growth ag. lab. force 1977-2000 (%/year)
Japan	8718	5.5	1.2	1.3	33	13	-9.03
Taiwan	1650	2.3	2.3	2.3	--	22	-3.84
Rep. of Korea	1500	3.9	3.9	2.8	66	36	-2.38
Malaysia	1370	4.0	5.0	2.6	63	51	0.71
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	0.97
Pakistan	270	4.5	3.0	2.6	61	57	1.86
Sri Lanka	230	4.0	2.0	2.0	56	51	0.92
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

Source: As cited in Asian Productivity Organization 1981, p. 5. Data for labor force in agriculture and country figures for Malaysia, Burma and Bangladesh from IBRD, World Development Report, 1981, pp. 134, 1970-71. Projected labor force growth rates Herdt, 1981a.

Table 2. Growth rates of total force, non-agricultural portion and resulting residual rate of growth in agricultural labor force, Asian countries, 1970-2000.

	Growth rate of labor force (%/yr) 1970-77	Growth rate of labor force (%/yr) 1977-200	Growth rate of non-ag. lab. force[a] 1970-75 (%/yr)	% lab. force in non-ag. 1977	Resulting calculated growth in ag. labor force (%/yr) 1970-75	Resulting calculated growth in ag. labor force (%/yr) 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
Rep. of 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

[a]Growth rate in urban population used as a proxy.

Source: Calculated from data in IBRD, World Development Project Report, 1979 and described in Herdt, 1981a.

Increases in rice production which have occurred during the past decade may be attributed to two major sources--expansion in the area under rice production, and increased 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 3 indicates that approximately 40% of the increase is from expanded area and the rest is 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.

Table 3. Growth rates (%/year) of rice production, area and yield compared to growth rate in agricultural labor force, 1970-1978 (Herdt, 1981a).

	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)[a]	3.07	0.99	2.08	-0.56	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, oilpalm)	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
Rep. of 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 the projected (1977-2000) rate of growth in agricultural labor force rather than that in 1970-75 because the latter actually registered a decline.

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 those figures which are accessible are usually unreliable or of indeterminate 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 (1981) recently completed a regional survey of mechanization in which both cross-country and temporal comparisons are made. Table 4 presents estimates of the power used in rice production for eight countries. While these figures represent average or regional approximations which conceal the wide variability which exists within countries, they do permit some useful interpretations. In the case of Japan, Rep. of Korea and Taiwan, 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 (Figure 1). Animal power is essentially non-existent in Japanese rice production. Machine hours are also beginning to decline after a high of 170 in 1970: evidence of the 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 (Table 5) combined with a high support price for rice continue to make labor use in rice production highly profitable.

Labor use in the Philippines, India, Pakistan and Nepal has increased during the period, largely as a 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 increasingly employ 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 also recent innovations in the rice production systems of Pakistan.

Table 6 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 clearly shown in Table 5 by the low levels of mechanical power available, although in some instances the estimates represent a high percentage of the total farm power supply. 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 machines contribute to the total power needs of agriculture. Nor do they give an indication of who uses the machines. Larger farmers may rely almost exclusively on mechanical power, while the smaller farms rely on animal and

Table 4. Estimated inputs of human, animal and machine power in rice production in selected countries of Asia, 1980 (hrs/ha).

Country	1965	1970	1975	1978
Japan				
Human	1401	1178	815	694[a]
Animal	15	2	--	--
Machine	144	185	179	148[a]
Taiwan[b]				
Human	1088	985	778	601
Animal	122	103	51	36
Machine	40	56	84	98
Rep. of Korea				
Human	1356	1284	1176	937
Animal	92	101	80	56
Machine	4	8	18	48
Philippines[c]				
Human	504	552	640	640[d]
Animal	200	136	136	136[d]
Machine	42	45	45	45[d]
Thailand[c]				
Human	490	480	470	462
Animal	170	165	160	146
Machine	10	15	20	30
India[e]				
Human	1218[f]	958	992	1285[a]
Animal	230[f]	247	221	125[a]
Machine	120[f]	na	na	113[a]
Pakistan				
Human	619	637	637	637[a]
Animal	312	308	284	128[a]
Machine	na	negl.	2	6[a]
Nepal				
Human	1200[f]	na	na	1448
Animal	312[f]	na	na	304
Machine	neg.	na	na	2

Source: Asian Productivity Organization, 1981.
a 1979; b first season crop only; c wet season crop; d 1977;
e average of Tamil Nadu and Orissa; f 1968.

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 regrettably not resolved the issues of the distributional or employment impact of mechanization on small farmers or landless laborers in these countries.

The wage and price information contained on Table 5 allow us to draw some rough correlations between the farm wage (expressed in term of rough rice) and the level of mechanization found in each country. There is a clear association in the case of countries from East Asia. Malaysia, Thailand and Burma also display a similar relationship, although the use of power tillers is not common in Malaysia and these smaller machines do not contribute as much as they do in Thailand. The Philippines and Indonesia have similar wage levels, but exhibit dissimilar patterns of mechanization. Clearly, these figures do not show the regional heterogeniety which exists in each country.

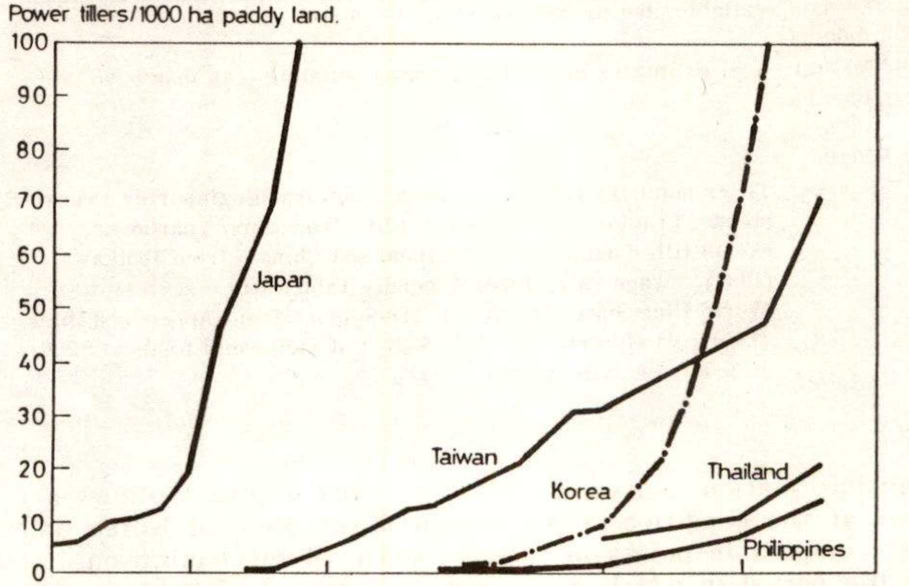

Figure 1. Number of power tillers per 1000 ha paddy land. (herdt, 1982)

Table 5. Power tiller and tractor numbers, wage rates and rice prices, by country, 1971-75 average.

	Tillers per 1000 ha cropland	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 ton
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	b	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	b	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	na	na	na

[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]1976.

[d]1978.

Source: 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 average $310/t of rice equal to about $200/t of paddy over the period 1971-75.

The information contained in Table 7 and Figure 1 allows a closer look at the conditions prevailing in Japan, Rep. of Korea and Taiwan at comparable points in their adoption of mechanization. Although the period in which mechanization began in Japan was different from that in Rep. of Korea and Taiwan, each country appears to have passed through four distinct periods. The introductory and early stages were characterized by low but rising real wage rates and a heavy reliance on external sources of technology. During the

Table 6. Estimated inventory of selected agricultural machinery per 100 hectares of arable land, 1979-80.

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
Taiwan	19.3	7.3	0.3	34.4	17.9	6.0	0.6	1.0
Rep. 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	-	-	-	-
Nepal	0.39	0.02	0.11	0.12	0.80	0.01	-	-

Source: Asian Productivity Organization, 1981.

-: Data not available or quantity used negligible.

Includes simple water lifting devices such as Persian wheels.

Table 7. Farm level rice prices and wage rates during comparable periods of agricultural mechanization, Japan, Korea and Taiwan (Herdt, 1981a).

State of mechanization		Period	Farm prices in Domestic currency: Per ton paddy	Farm prices in Domestic currency: Wage/day	Real wage kg paddy per day	Prices in US$: Per ton rice[b]	Prices in US$: Wage/day	Prices in US$: 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 tillers/1000 ha	1961	77 000	530	6.9	327	1.47	137
Republic of Korea								
Initial	Introduction	1961	14 360	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 column, converted to milled rice @ x 0.65, 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.

second and third stages, there was an accelerated increase in the proportion of the labor force in nonagricultural occupations, which served to raise the rural wage. Local adaptation and design transfer permitting the indigenous production of equipment became more pervasive, although importation of certain components continued. The source of much of the technology used in Rep. of Korea and Taiwan originated in Japan, and joint venture manufacture of power tillers and other equipment was common. The stage of full mechanization, at which there was one power tiller for each 10 hectares, was reached much earlier in Japan than the other countries. The time period between introduction and full use was also much shorter in Japan than either of the other countries, reflecting Japan's high degree of industrialization at the time mechanization began (following World War II).

A clearer picture of the sequence, pattern and growth of mechanization in Japan is given in Table 8. The first mechanical technologies were focused on the control and management of rice pests and on land preparation equipment. Because gravity irrigation and drainage systems were so well developed, it seems that water was not a constraint to sustained rice output at this time, and few water pumps were employed. With increased industrialization, there was further movement to introduce machines which enhanced the productivity of farm labor. Larger four-wheel tractors, threshers, binders, and finally small combine harvesters have all been important. Since

Table 8. Agricultural machinery in Japan (in thousands), 1950-1979 (Herdt, 1981a).

Year	Power tiller		Sprayers, dusters	Rice planting machines[a]	Threshers	Combine
	Walking type	Riding type				
1950	13		16		n. a.	
1955	63		88		1737	
1960	514		407		2458	
1965	2490	19	837		3048[b]	
1971	3201	267	2400	46	3279[c]	84
1976	3183	721	2899	1046	n. a.	428
1979	3168	1096	2618	1601	n. a.	747

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

[b] In 1964

[c] In 1968

Sources: For all data except threshers: for 1950-55: Institute of Developing Economies, 1969; for 1956-73: Kikuchi et al., 1975; for 1976-79: Ministry of Agriculture, Japan, Monthly statistics. For power threshers: McColly, 1973.

the mid-1970s there has also been a shift from two-wheel to larger four-wheel tractors. In the past five years the size of equipment has also increased and the number of tractors on Japanese farms is beginning to decline.

The history of mechanization in the contemporary developing countries has paralleled that of Japan, Rep. of Korea and Taiwan in several ways. The sequence has been similar. Land preparation equipment is inevitably the first technology employed. We also find that pest control equipment accounts for the largest number of machines in all countries. Almost all farmers either own or have access to a knapsack or pressure sprayer. In countries with a very limited water supply, such as Pakistan, irrigation pumps have been the priority mechanical technology. Recent evidence from the Philippines and Thailand indicates that threshing equipment has also begun to be used in large numbers (Juarez, 1978). With the exception of irrigation pumps, pest control equipment and some types of post-harvest machinery, most of these machines represent a clear substitution of capital for human and animal power. The evidence is not conclusive to demonstrate that tractors, for example, have augmented the area under cultivation or increased either cropping intensities or crop yields. The rationale for mechanizing land preparation must therefore lie in its profitability to the individual farmer and machine owner rather than in benefits attributable to increased output. There are clearly exceptions to this argument, as in the case of bringing additional land under cultivation by supplementing existing onfarm power supplies with machines. An example for realizing this type of potential is found in many of the transmigration areas in the outer islands of Indonesia. Most farmers fail to cultivate the full allotment of land because of insufficient power and the proper tools.

The Cost of Agricultural Machinery

A crucial question in the decision to invest in mechanized equipment is the initial cost. In Table 9, 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, Rep. of Korea and Taiwan. While these costs may partially represent export strategy of machinery supplies or the higher level of sophistication embodied in the machines (power steering, hydraulic controls, etc.) needed in these countries 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

Table 9. Ranking of nominal and real costs of 65 hp diesel tractors and 10 hp power tillers in selected countries of Asia, 1980.

Country	Nominal cost				Real cost[a]				Power available	
	65 hp		10 hp		65 hp		10 hp			
	($/hp)	rank	($/hp)	rank	(kg/hp)	rank	(kg/hp)	rank	(hp/ha)	rank
Japan	251	6	310	9	226	1	279	1	11.0	1
Taiwan	177	3	220	5	421	2	523	3	2.14	2
Rep. 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	0.33	5
Thailand	246	5	120	1	1607	5	784	4	0.16	8
Indonesia	413	9	440	11	1966	9	2095	9	0.03	10
Pakistan	172	2	-	-	1387	4	-	-	0.36	4
Sri Lanka	197	4	161	2	1728	6	1150	6	0.28	6
Burma	na	-	242	6	na	-	3967	11	na	-
Nepal	128	1	316	10	1040	3	2569	10	0.08	9
Bangladesh	na	-	300	8	na	-	1758	8	na	-

Source: IRRI surveys of 1977 and 1981. Asian Productivity Organization, 1981. Rice price data from Palacpac, 1980.

[a]Real costs are calculated by dividing the nominal cost of the machine by the farm gate price of 1 kg rough rice.

the dollar cost (using the domestic paddy rice) to a rice equivalent (kg/ha) representing the amount which a farmer must pay to acquire the machine. This figure reflects the real cost, and would be the key element entering the decision to acquire a machine. In this instance, the rankings of machine cost 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. Referring to Table 10, we find that in Japan, Rep. of Korea and Taiwan, 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 Rep. 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 the use of machinery in a number of the countries under review.

Table 10. 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	--
Taiwan					
1965	37	57	67	--	--
1970	43	58	67	--	--
1975	100	100	100	100	100
1979	139	--	167	175	163
Rep. of Korea					
1965	17	27	21	--	--
1970	33	45	25	--	--
1975	100	100	100	100	100
1979	201	158	110	385	194
Malaysia					
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

Cont'd Table 10.

Country	Paddy price	Farm machinery	Fuel	Rural wages	Draft animals
Nepal					
1965	65	40	33	--	--
1970	75	61	65	--	--
1975	100	100	100	100	100
1977	110	127	108	118	120

Source: Adjusted from Asian Productivity Organization, 1981. Prices for draft animals from surveys. Price data for Malaysia from Palacpac, 1980.

Mechanization and Other Inputs

There is an extensive literature on the adoption of the modern rice varieties in Asia (Herdt, 1981a; Palacpac, 1980; IRRI, 1975). It is generally accepted that the technology currently available is highly location-specific, being most readily accepted in those areas with good soils, irrigation, and access to supporting credit and input markets. There is also evidence indicating mechanization is most widely employed in many of these same areas (IRRI, 1975). Higher yields make adoption and use of machines more profitable to farmers and less risky to investors. For a specific case, we refer to information from Laguna and Central Luzon Provinces in the Philippines. Table 11, taken from a 1978 household enumeration of eight villages in Central Luzon, a major rice growing area, shows that 60% of these farmers owned or used mechanized equipment for primary tillage. Many, however, used water buffalo for secondary tillage or owned them as insurance against nonavailability of tractors and power tillers. The same survey showed that farmers may change their choice of technique depending on the season, yield of the previous crop and cost of land preparation.

In Laguna, the pattern of adoption is clearly shown over time (Table 12). Table 13 indicates the gradual increase in machine owners and decline in the number of water buffalo.

Mechanization and Employment

It was clear in examining the evidence from Japan, Rep. of Korea and Taiwan that the principal motivation for 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 to production (land, water, credit) poses the danger of inequitable distribution of gains from increased agricultural productivity. Many voice concern that machines may exacerbate an already precarious level of income for small farmers and landless laborers (Herdt, 1981b; Sisler, 1979).

Table 11. Number of farmers by method of primary tillage used, 8 villages in Nueva Eija, Philippines, wet season, 1978.

Method of primary tillage	No. of Farmers	%
Animal	380	41.4
Two-wheel tractor	371	40.4
Four-wheel tractor	142	15.5
Two- and four-wheel tractor	25	2.7
Total	918	100.0

Source: Household census, Consequences of small rice farm mechanization project, Ag. Eng. Dept., Int. Rice Res. Inst., Los Banos, Philippines.

Table 12. Adoption of mechanized land preparation in Laguna, Philippines, 1965-78 (%).

Operation	1965	1970	1975	1978
Plowing	0	11	20	47
Harrowing	24	69	89	93

Source: Smith, J. and F. Gascon, 1979.

Table 13. Farmers owning tillage machines and water buffalo in Laguna, Philippines, 1965-78 (%).

Farmers owning	1965	1975	1978
Machine	15.5	17.8	16.7
Water buffalo	75.6	57.8	35.6

Source: Smith and Gascon, 1979.

The data available indicate that as mechanized land preparation is introduced, it is primarily family and animal labor which is replaced. The evidence in Table 14 supports this finding. For 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 be displaced. 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 15). Although the relative proportion of hired labor and the real wage in the threshing operation both increase, the total number of man-days required is reduced. The net effect is a reduction in earnings by hired labor. As much of this equipment is locally produced and maintained, it is unclear if overall net wage incomes have declined.

Table 14. Labor inputs for wet season irrigated rice production at three locations in Asia (man-days/ha).

Year	Site		Manual	Animal	Partly mech.	Mech.
1979	Philippines	No. obs.	--	(46)	(94)	(54)
		Family	--	29.7	6.2	4.6
		Hired	--	53.9	58.5	54.1
		Total	--	83.6	64.7	58.7
1981	Thailand	No. obs.	--	(49)	(120)	(100)
		Family	--	34	30	26
		Hired	--	26.2	24	20
		Total	--	60.2	54	46
1979-80	West Java	No. obs.	(55)	(76)	(117)	(27)
		Family	36	59	14.7	28.2
		Hired	144.8	159.6	141.2	219.4
		Total	180.8	218.6	155.9	247.6
1979	South Sulawesi	No. obs.	--	(82)	--	(76)
		Family	--	54.1	--	28.2
		Hired	--	49.7	--	75.3
		Total	--	103.8	--	103.5

Source: Site reports from Mechanization Consequences Project. Agricultural Engineering Department, IRRI, 1982.

Table 15. Labor requirements for harvesting and threshing before and after adoption of mechanical threshers. 1978-79 wet and dry season. Iloilo, Philippines (man-days/ha).

	Irrigated	Rainfed
Before thresher adoption		
Hired system[a]	39.7	36.2
Contractual system[b]	51.9	--
Average	42.6	36.2
After thresher adoption		
Hired system	15.9	16.4
Contractual system	24.2	--
Average	18.4	16.4
No thresher adoption		
Hired system	45.7	42.0
Family system	34.0	--
Average	44.0	42.0

[a] The "hired" system employs labor paid a share of the crop, and is open to all outside labor.

[b] The "contractual" system provides payment as a percentage of the crop and involves the responsibility for carrying out tasks such as weeding as a condition of

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

Mechanization and Output

Farm mechanization can potentially affect output in four ways: (1) it can increase yields; (2) it can increase cropping intensity; (3) it can expand cultivated area; and (4) it can reduce losses and improve quality in post-harvest operations. In Table 16 we have attempted to assemble the available evidence describing the impact of mechanized land preparation on crop yields. If proper adjustments are made for the level of other inputs such as fertilizer, there appears to be no significant difference in the output per hectare from farms using mechanical methods and those using animal or manual techniques. One exception is the study reported by Tan and Wicks (1982). There appears to be little physiological basis for yield increments resulting from land preparation methods under lowland conditions. Experiments conducted by Duff (1978) using five alternative land preparation methods failed to demonstrate significant differences in yields (Table 17), although the experiment did show a direct relationship between weed population and yield. While the above generalization appears to be true for wetland rice, it is unlikely the same results will hold true for dryland crops such as wheat, corn and sorghum, which may react more positively to a higher quality seedbed than rice under flooded conditions.

Table 16. Summary of studies comparing yields on farms with animal or hand land preparation with farms using mechanical methods.

Author	Area	Comparison	Reported yield (t/ha)	Fertilizer (urea) (kg/ha)	Adjusted yield (t/ha)
Pudasaini	Nepal	Bullocks vs.	1.7	16	1.7
	(without pumps)	tractors	2.1	164	1.4
Pudasaini	Nepal	Bullocks vs.	2.1	214	2.1
	(with pumps)	tractors	2.3	264	2.1
Sinaga	West Java, Indonesia	Animal vs.	4.9	323	4.9
	(wet season, 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	Animal vs.	2.7	138	2.7
	(3 seasons, 1979/80)	tractors	2.9	227	2.5
Tan and Wicks	Nueva Ecija, Philippines	Buffalo vs.	2.6	89	2.6
	(wet season, 1979)	tractors	3.0	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	n.a.	1.5
		power tiller	1.5	n.a.	1.5
Deomampo & Torres	Central Luzon, Philippines	Before vs. after	2.2	57	2.2
		tractors & tillers	2.6	79	2.1
Antiporta & Deomampo	Philippines & provinces	Animals vs.	2.6	86	2.6
		tractors & tillers	2.8	117	2.5

Table 17. Labor and fuel used in experiments on five alternative land preparation methods for rice production (average of 4 soil types, Philippines, 1973 wet season).

Primary tillage	Secondary tillage	Labor (hr/ha)	Fuel (liter/ha)	Weeds ($g/0.2 m^2$)	Yield (t/ha)
64 hp tractor	Buffalo	45	20	16.7	3.61
14 hp tiller	Buffalo	49	15	12.3	3.56
7 hp tiller	7 hp tiller	29	36	11.0	3.81
Buffalo	7 hp tiller	56	26	14.4	3.60
Buffalo	Buffalo	81	0	17.9	3.60

Source: Duff, 1978.

It is clear that use of tractors and power tillers for land preparation represents only one possible source of higher yields. There is little doubt that better methods of weeding, fertilizer application, and pesticide control can produce increased yields compared to many traditional methods. The high population of hand sprayers found in all countries of Asia is strong evidence of this observation.

A second major source of potential production increases from mechanization is the impact which it may have on crop intensification or the number of crops grown each year. Those arguing for mechanization to achieve intensified cropping have cited the need for more timely harvesting and threshing, combined with rapid land preparation for the second (or third) crop to maximize use of scarce water, land and solar energy resources. The evidence on the intensification issue is more ambiguous than that for yields. Table 18 combines the results from a number of studies which have attempted to examine this issue. For the irrigated areas of the Philippines the effect appears to be positive, although with a wide degree of variability between sites and environments. Nepal and India also show slight gains from use of tractors and power tillers, although these were not statistically significant at any of these sites. The work of the Mehcanization Consequences Project in Indonesia shows slightly lower cropping intensity on farms employing mechanization than for those using traditional methods. Again, however, the differences are small, tending to indicate power for land preparation is not a major constraint in these farming systems. Changes in the irrigation scheduling system, combined with efforts to foster a three crop system in West Java, have increased concern that there may not be sufficient labor and animal power available to maintain existing the cropping intensity without provision of supplemental power for land preparation.

Table 18. 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	Buffalo vs. power tillers	1.03 (Poor Irrigation) + 5%
King, 1974	Central Luzon, Philippines	Buffalo vs. power tillers	1.70 (Good Irrigation) + 2%
IRRI, 1980	Central Luzon, Philippines	Buffalo vs. tractors	1.37 (Irrigated) + 44%
IRRI, 1980	Central Luzon, Philippines	Buffalo vs. tractors	1.00 (Rainfed) 0
Pudasaini, 1979	Bara District, Nepal	Animal vs. tractors[a]	1.45 + 14%
Pudasaini, 1979	Bara District,	Pumpset vs. tractors and pumpset	1.55 + 12%
NCAER, 1977	South, East India	Bullocks vs. power tillers	1.41 + 2%
Ahmed, 1975	Bangladesh	Bullocks vs. power tillers and 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 (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.

The evidence from Japan, Taiwan and more recently from Rep. of Korea shows that these countries achieved their maximum cropping intensities before the advent of mechanized land preparation, although the ability to sustain high levels of cropping intensity following structural transformation was clearly due to the availability of mechanical devices which supplemented available supplies of human and animal labor.

The use of mechanical threshing has been examined in the Philippines (Table 19). The results are similar to those for land preparation. The ability to plant a second or third crop appears to be determined largely by the timing of water deliveries and the synchronous planting of groups of farmers to minimize the risk of pest damage, rather than by constraints on harvesting and threshing operations.

Table 19. Summary of studies on the impact of mechanized threshing on cropping intensity in rice-based systems, Asia.

Study	Area[a]	Cropping intensity	
		With power threshing	Change
Juarez, 1979	Iloilo	1.68 (Irrigated)	+13%
Juarez, 1979	Iloilo	1.55 (Rainfed)	+ 4%
Juarez, 1979	Laguna	1.43	+22%
IRRI, 1980	Central Luzon	1.78 (Irrigated)	-23%

a: All in the Philippines. All these studies compared hand with power threshing.

The third possible source of increased output resulting from mechanization is an expansion in the land under cultivation. The historical evidence from the United States, Canada, and the Soviet Union illustrates that it was the introduction and use of mechanical devices such as the McCormick reaper, the crawler tractor and the wheel tractor which allowed these countries to expand the area under crops during the period of the late 1800s and early 1900s. In most Asian countries, however, the land frontier is closed and the opportunity for expansion in cultivated area is limited. The data gathered by Binswanger (1982) describing the development of mechanization in Thailand supports the hypothesis that growth in the cultivated area over the past three decades is highly correlated with the introduction of tractors and power tillers. A similar potential appears to exist in Burma, which has extensive unused land resources. The transmigration areas of Indonesia may also harbor similar opportunities. The data we have available does not, however, indicate a clear relationship between mechanization and growth in the cultivated area.

As a general rule, it is unlikely that the use of mechanization will result in more land being brought under crops in countries where the land available for development is limited or the cost of development is high, and the cost of alternatives such as labor and animal power are low.

Domestic Manufacture of Agricultural Equipment

Most Asian 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 encouraged 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 example 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 et al., 1978).

For those responsible for 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.

The following sequence of activities seems necessary (although not always sufficient):

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

The system must be responsive to review and evaluation at any step in the sequence of activities. For example, the need for a technology identified at step 1 may prove intractable to solution at the conceptual or development stages. A more difficult case would be the instance when a technology passes through steps 1 to 4, but upon review it is found the resulting machine 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 the International Rice Research Institute's industrial extension program working closely with local agencies in six Asian nations. 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 gradually 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 Planners, Engineers and Economists

There is a need to develop a consistent, consolidated and comprehensive strategy for the mechanization of small rice farms. We suggest the following as urgent topics for agricultural mechanization planning and research in the 1980s:

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

2. Clarify the benefits and costs of mechanization at both the micro and the macro levels. What impact do machines have on crop yields, intensity, cropping patterns and area under cultivation? What is the value of increased hp-hrs/ha? Who benefits? Is there a major difference between the private and social profitability of mechanization? Which criteria should be used in identifying the need for agricultural engineering technologies?

3. What are the immediate and long run income and employment effects of policies to encourage rural-based industrial activities? What are the multiplier effects of income-generating developments in this subsector?

4. What is the likely impact of rising energy costs in the Asian region on agricultural development, and what engineering innovations are needed to ensure these costs do not retard further increases in production?

5. In areas which have been untouched by the modern varieties, what can engineers contribute to improve the likely development and use of improved technology for the conditions found in these areas?

6. Lastly, what are the component elements and the minimum critical size of an agricultural mechanization development program?