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9. ABSTRACT

The major conclusions of this study are as follows: 1) The horsepower per hectare available to the agricultural sector is extremely low in most less developed countries. 2) Mechanization, over the run, is the only viable means of increasing agricultural horsepower per hectare. 3) Fossil fuels are likely to be the main energy source for mobile agricultural equipment for at least the next twenty to thirty years. 4) In its early stages, mechanization usually has very little, if any, effect on crop yields. 5) In its early stages, mechanization may be associated with a slight increase in multiple cropping and some minor adjustments in the types of crops grown. 6) Mechanization which replaces animal power usually results in a reduction in labor inputs. 7) Non-agricultural employment engaged in the manufacture, distribution, repair, and maintenance of farm equipment replaces only a small part of the displacement in on-farm employment resulting from mechanization. 8) Tractorization programs may result in a gradual increase in the size of land holdings and the displacement of tenants or farm workers, unless there are institutional factors or government policies to prevent or discourage such trends. 9) Government policies and programs to promote mechanization through subsidized interest rates, favorable import arrangements, or increased credit availability can cause a significant increase in the rate of mechanization and are likely to benefit large landholders more than others. 10) Finally, the mechanization of agriculture is a continuous and inevitable process in economic development but one whose speed and direction can be altered by public policies and programs.

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THE IMPACT OF AGRICULTURAL MECHANIZATION ON EMPLOYMENT AND FOOD PRODUCTION

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September, 1975

Occasional Paper No. 1

Economics and Sector Planning Division
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SUMMARY OF MAJOR CONCLUSIONS AND RECOMMENDATIONS

The following major conclusions are either documented in this paper or can be documented from data in other studies of agricultural mechanization.

1. The horsepower per hectare available to the agricultural sector is extremely low in most LDC's. Mechanical horsepower per cultivate hectare usually is less than 0.3 hp in Latin America, 0.1 hp in Asia (excluding Japan and Taiwan), and frequently below 0.02 hp in Africa. Increases in agricultural production will require increases in agricultural power and better utilization of available energy sources.

2. Mechanization is the only viable means of increasing agricultural horsepower per hectare over the long run. As the quality and quantity of arable land per capita diminishes, the food energy for men and animals will become increasingly expensive. Mechanization, in a sense, reduces the demand for food.

3. Fossil fuels are likely to be the main energy source for mobile agricultural equipment for a least the next twenty to thirty years. Conservation of fossil fuels will require increased use of other energy sources (solar radiation, wind, gravity, agricultural by-products) for stationary equipment such as grain dryers and irrigation pumps.

4. In its early stages, mechanization usually has very little, if any, effect on crop yields. In actual practice, it appears unlikely that deeper plowing, better weed control, or improved grain harvesting resulting from mechanization will increase yields by more than 10 percent.

5. In its early stages, mechanization may be associated with a slight increase in multiple cropping and some minor adjustments in the types of crops grown. The introduction of tube wells and irrigation pumps appears to have a much greater effect on cropping intensity than other types of mechanization. In general, the observed increase in cropping intensity which can be attributed to mechanization probably is seldom greater than 10 percent. In most cases mechanization is "pulled in" by increases in the intensity of cropping or its potential--rather than multiple cropping being "induced" by mechanization.

6. Mechanization which replaces animal power usually results in a reduction in labor inputs. The amount of the reduction in labor inputs depends on the particular crops, farm size, and extent (as well as type) of mechanization. During the early stages of mechanization of grain production, labor requirements may be reduced by as much as 30 to 40 percent.

7. Non-agricultural employment engaged in the manufacture, distribution, repair and maintenance of farm equipment replaces only a small part of the displacement in on-farm employment resulting from mechanization. Rough estimates based on the limited data available suggest that each man-year in farm employment created by the agricultural machinery industry results in a displacement of on-farm employment of at least 20 man-years over the life-time of the equipment produced.

8. Tractorization programs may result in a gradual increase in the size of land holdings and the displacement of tenants or farm workers unless there are institutional factors or government policies to prevent or discourage such trends.

9. Government policies and programs to promote mechanization through subsidized interest rates, favorable import arrangements, or increased credit availability can cause a significant increase in the rate of mechanization and are likely to benefit large landholders more than others.

10. The mechanization of agriculture is a continous and inevitable process in economic development but one whose speed and direction can be altered by public policies and programs. There is no single indicator as to whether or not a particular machine is appropriate for a particular nation as a starting point, however, it is useful to ask. "Can a particular machine be produced profitably domestically without substantial government subsidization?"

The following recommendations are based on the assumption that developing nations are interested in increasing agricultural output while at the same time minimizing unemployment and, to some extent, improving the distribution of income. They also reflect a basic assumption that increased mechanization will be necessary in the long run if rural welfare is to be improved significantly.

1. Government should not subsidize the manufacture, importation, purchase or use of tractors through special exchange rates or low-cost credit programs. Such programs have seldom benefitted the majority of the farm population or led to substantial increases in production.

2. Governments should support the development of agricultural machinery which can be used profitably by a large proportion of the nation's farmers and, to a large extent, can be produced domestically without government protection or subsidization.

3. Highest priority should be assigned to the development of small scale equipment which can effectively utilize non-fossil fuel energy. (As examples: the use of wind for pumping water or the use of rice hulls for drying grain.)

4. The development of low cost irrigation pumps and other mechanical devices to improve the effectiveness of water control systems should also receive high priority. Water control is a critical element in multiple cropping systems. Furthermore, water is likely to become an increasingly scarce resource; one not to be wasted with inefficient irrigation systems.

5. Additional research should also be undertaken on ways to improve the effectiveness and efficiency of small scale farm equipment. (Can plows or rotary tillers be designed, or redesigned, which will require less energy, smaller tractors, to effectively cultivate land? Can small threshers, dryers, and grain mills be improved to further reduce grain losses? etc.)

6. Agricultural mechanization should be viewed as a part of modern agricultural production systems. Mechanization alone has little effect on yields or cropping intensity and usually will result in a reduction in employment per unit of output. Combined with new biological and chemical technologies, however, mechanization may enable more precise timing of operations and application of chemical inputs so that the total biological, chemical, and mechanical package results in an increase in output per acre year with little, if any, reduction in total employment.

The mechanization of agriculture has contributed tremendously to the economic progress of the more developed economies. Advances in mechanical technology have enabled the introduction of improved cultivation practices, the effective use of modern inputs, and increases in farm size. This usually has resulted in a major movement of people out of farming and substantial increases in farmers' productivity. Whether the farm mechanization strategies followed by the more developed nations are suitable for developing nations, however, is questionable.

I. Types of Farm Mechanization

Farm mechanization is the process of introducing tools, machinery, and equipment for producing agricultural products. Such implements basically transform energy and focus it on a particular task. Mechanization can result in the more effective utilization of energy or the replacement of one energy source by another. A change of energy sources may have significant social and economic effects, especially when it occurs rapidly. Government policies can affect the type and speed of mechanization as well as the distribution of its social and economic benefits and costs.

A farmer's technical opportunities for mechanization depend partly on whether he produces grains, livestock, fruits, vegetables, tree crops, flowers, tobacco, or sugar crops. Government programs to promote farm mechanization have emphasized grains. Rice, corn, and wheat usually are the most important food crop, frequently are produced by a large proportion of a nation's farmers, and offer a wide range of technical alternatives for mechanization. The data available on the impact of technology applies to the mechanization of grain production.

Producing grains involves land preparation, water control, planting, weed and pest control, harvesting, and some on-farm processing. Each operation requires a different type of mechanization but the mechanization employed in one operation is seldom independent of that used in other operations. This makes it extremely difficult to estimate either the output or employment effects of mechanizing a particular operation. The introduction of tractors for land preparation, for example, may have little effect on output unless water availability is increased with tube wells. The investment in tube wells, on the other hand, may yield the greatest returns only when tractors and associated equipment can be used to reduce the time required for land preparation and harvesting thereby allowing multiple cropping.

The set of mechanical alternatives for producing grain contains numerous subsets defined for particular grains and specific geographic and climatic environments. Each subset involves a different combination of labor utilization and yields. Only a

few of these subsets have been studied carefully. The majority of the studies have been concerned with the introduction of two-wheel tractors (7 to 15 hp) for rice production and the use of larger tractors (30 to 70 hp) for rice, cotton, and wheat production. Most studies emphasize the early stages of mechanization and are concerned particularly with how a new machine affects early adapters' decisions, use of resources, and income over a three to five year period. The short and intermediate term impacts of mechanization may be quite different from the long term impacts. Nevertheless, it is the three to five year impacts which usually are of greatest interest to ministries of agriculture and international lending agencies.

II. The Role of Mechanization in Agricultural Development

Farm mechanization frequently is equated with modernization and moderization, in turn, with high productivity of the land and labor resources employed in agriculture. In the process, farm mechanization frequently is viewed as an essential part of, if not the first step towards, agricultural development. It is argued that mechanization can, and will, increase agricultural output and employment by bringing more land into production, increasing multiple cropping, and improving cultivation practices. There is no way to prove or disprove such a general claim. The available studies on specific mechanization programs, however, show clearly that the benefits of mechanization are not obtained without costs and that the costs at times exceed the benefits.

Over the long run the mechanization of agriculture permits structural change in an economy by allowing labor to be shifted to other activities without a resulting reduction in agricultural output. This process is readily documented where mechanization and structural changes have occurred relatively rapidly as in the United States. It is less easily observed where population has increased more rapidly than the rate of mechanization. In such cases the proportion of the total labor force employed in the agricultural sector may change very little if at all as mechanization occurs. It is always difficult to determine whether labor is being "pulled out" of the agricultural sector by external forces or "pushed out" by mechanization. Machines usually are simply "enabling devices" which allow structural changes to occur. In other words, the machines themselves do not "induce" or "cause" much of the structural change.

From the viewpoint of the individual production unit, the decision to substitute machinery for labor or animals may be a response (a) to changes in the relative prices of inputs or (b) to a shift in the production function which increases the marginal productivity of machinery. The availability of new machines may allow farmers to use their existing resources more intensely, change the timing of farm operations, introduce new crops, increase the size of their farms, and change the composition of labor inputs. Numerous efforts have been made to measure the effect of mechanization, especially the introduction of tractors, on yields, the intensity of land use, and on-farm employment. Several of these studies will be discussed later.

Agricultural mechanization may directly effect the non-farm population by creating new jobs in the manufacture and maintenance of farm machinery and through the development of new job skills. The development of an agricultural machinery industry also has both direct and indirect effects on other industries. The off-farm effects of agricultural mechanization have not been as carefully studied as the on-farm effects. Much of the analysis has been concerned primarily with estimating the off-farm employment associated with farm mechanization.

III. The Extent of Agricultural Mechanization

The FAO estimates of mechanical horsepower per hectare in 1967-68 for selected countries are presented in Table I. They range from 0.01 in India to 3.09 in Japan. Human power available to agriculture for the countries considered in Table I ranges from 0.10 to 0.25 horsepower per hectare depending primarily on population densities. Animal power in most of these countries is in approximately the same range (Stout and Downing, 1974). Agricultural power (human, animal and machine) available in Africa has been estimated to be as low as 0.05 horsepower per hectare; far below that available elsewhere (Giles, 1967). The high level of mechanical power available in Japan reflects the widespread use of small two-wheel tractors and intensive land utilization.

TABLE I: MECHANICAL HORSEPOWER AVAILABLE IN SELECTED COUNTRIES

Country	Mechanical HP Per Cultivated Hectare 1/
Japan	3.09
West Germany	1.94
United Kingdom	1.57
France	1.52
United States	0.96
Italy	0.89
Uruguay	0.45
Argentina	0.31
Chile	0.23
China, Rep. of	0.15
Peru	0.15
Mexico	0.11
Thailand	0.05
Bolivia	0.03
Pakistan	0.01
India	0.01
U.S.S.R.	0.01

Notes:
1/ Most estimates based on 1967-68 data.

Sources:

a. Latin American estimates are based primarily on FAO data reported by K.C. Abercrombie, "Agricultural Mechanization and Employment in Latin America," in Mechanization and Employment in Agriculture, Geneva, ILO, 1973.

b. Data on other countries based on FAO data reported by B.A. Stout and C.M. Downing, Selective Employment of Labor and Machines for Agricultural Production, Michigan State University, Institute of International Agriculture, Monograph No. 3, April 1974.

IV. Mechanization and Yields

During the early stages of mechanization most new machines have little effect on yields. Although some studies report a high correlation between horsepower per hectare and yields or find that farms using tractors have higher yields, a closer look usually reveals that the higher yields are the result of using improved varieties, more fertilizer, better water control, or improved cultivation practices rather than machines per se. It appears that yield increases accounted for by mechanization alone are seldom greater than 10 percent. Many researchers assign almost all yield increases to other technological changes which frequently occur simultaneously with, but independent of, mechanization. McInerney and Donaldson (1973), for example, analyzing the consequences of farm tractors in Pakistan, conclude that there is "no convincing evidence of beneficial changes in crop yield associated with tractor use" and that the observed yield increases could "be attributed largely to increased fertilizer use."

One of the most careful surveys of available evidence on the relations between tractorization and crop yields was carried out by Singh and Chancellor (1973). The results of the main studies which they reviewed are presented in Table II. Some of the studies are based on field experiments; others on surveys of farms using different power sources. At first glance the data suggest that the crop yields on tractor farms are slightly higher than those on bullock farms in many, but not all, instances. Statistical analysis of the sample data underlying Table II reveals that the yield differences are rarely significant at the 10 percent level of significance.

The field experiment data from the Philippines in Table III show a 12 percent reduction in sweet potato yields when two-wheel tractors are used to replace carabao. The use of hand tractors had little effect on rice yields but substantially reduced yields of cowpeas interplanted with corn while having only a slight negative effect on corn yields.

TABLE II: COMPARISON OF YIELDS UNDER BULLOCK AND TRACTOR USE

Crop	Tractor Farms (lb/acre)	Bullock Farms (lb/acre)	Ratio Tractor to Bullock
	(1)	(2)	(3)=(1)÷(2)
		West Malaysia (1949 - 50) 1/	
Rice	1280	1221	1.05
		West Pakistan (1952 - 54) 2/	
Sugarcane (Stripped)	8530	7300	1.17
Cotton	857	1073	0.80
Corn	1720	1307	1.32
Wheat	1385	1049	1.32
Oilseed Crops	965	800	1.21
		West Pakistan (1969) 3/	
Cotton	1042	919	1.13
Corn	1730	1496	1.16
Wheat	2533	2365	1.07
Sugarcane	41,500	40,500	1.02
		Philippines (1967) 4/	
Rice	3231	3299	0.98
		Taiwan (1970) 5/	
Rice	3109	3183	0.98

Notes:

1/ Department of Agriculture, Federation of Malaya, 1953.
2/ Gill, 1961.
3/ Ahmad, B., 1970.
4/ IRRI, Annual Report, 1967.
5/ Hu, C.H. Chuen-Bang Young, and Ten Kian Huang, 1971.

Complete citations of references are presented in the bibliography.

TABLE III: COMPARISON OF YIELDS FROM THREE POWER SOURCES, PHILIPPINES, 1973

Crop	Hand Labor (1)	Carabao (2)	Hand Tractor (3)	Tractor-Carabao Ratio (3) ÷ (2) as %
Rice (tons/ha)	2.3	2.4	2.4	100
Sweet Potato (tons/ha)	9.4	9.4	8.3	88
Cowpea with Corn (tons/ha)	1.2	1.1	0.8	73
Corn with Cowpea (1000 marketable ears/ha)	32	31	30	97

Source: Gordon R. Banta, 1973.

Many of the tractorization programs of the 1960's were promoted with the claim (or assumption) that increased mechanization would result in higher crop yields. In many cases the claim appears to have become a belief and the belief a part of the conventional wisdom. There are several reasons why yield increases due to mechanization may not be observed during the early stages of mechanization. First, the introduction of tractors, with other technological inputs unchanged, merely represents a substitution of one power source (tractors) for another (usually animals). Second, farmers seldom mechanize all of their cultivation operations during the early stages of mechanization. Land preparation usually is the first operation mechanized while other operations continue to be performed with animal power. More complete mechanization may be required to obtain a significant increase in yields. Mechanization of secondary operations, for example, may allow more precise application of fertilizers, pesticides and herbicides and result in higher yields. At least part of such yield increases should be attributed to mechanization. Third, the implements or cultivation procedures used in land preparation in actual practice may not result in a significantly better seed bed than obtained prior to mechanization. The farmer, in an effort to reduce costs or save time, may not fully utilize the additional power which tractors provide or may farm soils where deeper plowing is of little value. When mechanization does result in better seed beds, this may reduce the need for, or cost of, later cultivation operations but have little effect on yields. Deeper plowing, for example, may reduce weed growth and as a result reduce weed control costs without any effect on yields.

There are a large number of economic, social and technical factors which affect the way machines are used during the early stages of mechanization and thus the impact they may have on yields. Farmers seldom switch from animal to machine power with the expectation of higher yields from the change in power sources alone. They may, however, recognize that in some cases machines will enable them to use chemical and biological technologies that will increase yields. Land preparation is one of the most difficult operations, it is hard work for both the farmer and his animals. The timing of land preparation to allow for compatibily with irrigation schedules and planting seasons is recognized by farmers to be important. Although land preparation by machine may cost more than by animals, the difference may be less than the value of the reduced work load for the farmer and the flexibility in timing operations.

The cost-value structure changes continuously over time and differs between farmers. Government policies can affect both sides of the equation. In the Philippines, for example, rice price policies and green revolution technology packages increased the value of flexibility in timing operations while higher farm incomes probably allowed farmers to consider alternative ways to reduce their work load. Carabao costs began to increase in some areas partly due to increased demand and partly as a result of a reduction in carabao numbers due to serious floods. Local manufacturing of IRRI designed two-wheel tractors reduced the cost of machine services. As a result, cost differences became small enough to induce an increasing number of farmers to purchase or rent small tractors.

In a survey of 150 rice farmers adopting small tractors in the Philippines, 60 percent indicated they purchased tractors because of the problems and nuisance value connected with carabao maintenance. (Alviar, undated). A somewhat smaller number indicated that savings in time was an important reason for purchasing a tractor. Farmers apparently felt the savings in time was important for various reasons. First, less time spent in land preparation allowed more time for other productive activities. For the farmers sampled, fishing and duck raising frequently provided additional family income. Second, farmers apparently were aware that more rapid land preparation provided greater flexibility in planting times. Being able to plant earlier allows a wider choice of rice varities, may help overcome labor shortages and drying problems at harvest time, and can facilitate multiple cropping. Finally, and in some cases perhaps most important, the shift from carabao to small tractors probably increases a family's leisure time as well as making some cultivation and harvesting tasks easier. Where small tractors completely replace carabao the largest saving in time is that previously devoted to caring for the carabao. In summary, the survey results suggest that Philippine rice farmers adopting small tractors anticipated very little, if any, direct yield effect from mechanization. They adopted tractors because they believed that tractors would make their life easier and would allow them to alter the timing of field operations in ways that could reduce costs or facilitate more intensive land utilization.

Similar results were reported in a 1967 survey in Thailand (Royal Thai Government, 1969). Farmers who used tractors considered the greater physical ease in accomplishing work and the time freed to earn income from other sources as more important than the possible cost or output advantages of tractors compared to other power sources. The timing of farm operations appeared to be more important on large farms which had a shortage of farm labor and draft animals during peak farming seasons. The Thai study team reported that, in general, the larger the farm the smaller the yield for most crops. They suggested that increased mechanization could result in higher yields on larger farms by enabling them to overcome labor shortage problems. They did not, however, report whether large farms having adequate tractor power did indeed have higher yields than large farms with less tractor power.

The timing of agricultural operations frequently has been noted to have an important effect on crop yields. In Kenya, corn planted to take advantage of early rains reportedly yields over 50 percent higher than that planted a month later. Early weeding was found to increase corn yields by another 25 percent (Voss, 1974). In Turkey cereals planted in October resulted in a 38 percent higher return than those planted in November. In India it has been estimated that for each day's delay in planting after the optimum period there is a one percent reduction in wheat yields. Such evidence does not prove, however, that farmers need tractors in order to plant or cultivate their crop on time. Nor does the existence of technical opportunities to increase yields by altering planting dates automatically assure that farmers with tractors will take advantage of the opportunities.

The yield effect of tractorization has not been studied as carefully in Africa or South America as in Asia. Abercrombie, after reviewing the available information on mechanization in South America, concluded that "better soil preparation, including such operations as deep ploughing and subsoiling that are only possible with mechanization, increases yields per hectare" (Abercrombie, 1972). This judgement, however, is based on little empirical data and, if true, would apply primarily to heavier soils. Statistical studies by other researchers have not revealed a strong yield effect. William R. Cline, for example, used regression analysis to separate the yield effect of tractors and fertilizer for 117 rice farmers in southern Brazil (Cline, 1970). His results showed that, at most, the use of tractors increased yields by only two percent.

Clayton, attempting to determine the advantages and disadvantages of mechanization in Africa, concluded that "increased yields can result from better seed-bed preparation, particularly in the case of heavy soils, and/or more timely operations, including planting" (Clayton, 1972). This observation reflects conventional wisdom more than

empirical data and fails to separate the "enabling" effect of machines from the direct yield effect. It was qualified later in Clayton's study with the statement that the improved yields observed with tractor cultivation in Africa "have often been due to the accompanying introduction of improved seeds, fertilizer and insecticides."

V. Mechanization and Intensity of Land Use

Another advantage claimed for mechanization is that it allows more intensive land utilization. The evidence to support this claim is inconclusive. Many, but not all, studies report more intensive cropping on tractor farms compared to bullock farms. Few of the studies however attempt to separate the cropping intensity impact of tractors, or of tractors as enabling devices, from the other factors that may account for a substantial part of the higher level of cropping intensity sometimes observed on tractor farms. Farmers using tractors, for example, may have greater access to credit, more capable managers, or better water control systems.

Several comparisons of the intensity of land use on tractor farms vs bullock farms are presented in Table IV. The 23 percent difference in cropping intensity reported in the Philippines is in part accounted for by better water control systems on the tractor farms included in the study. The IBRD study on the consequences of farm tractors in Pakistan by McInerney and Donaldson (1973) is one of the more careful efforts to estimate the cropping intensity effect of tractors. They found cropping intensity on tractor farms to be seven percent greater than on bullock farms during the 1966-70 period.

The degree of cropping intensity may increase over time on tractor farms. If so, a short run comparison of tractor farms and bullock farms may underestimate the longer run impact of tractors in enabling more intensive land utilization. There is very little data, however, on changes in cropping intensity over time resulting from mechanization. A research team reviewing the 1957-67 data on tractor use in Thailand concluded that the availability of farm equipment did not significantly effect farming cycles or the extent of multiple cropping (Royal Thai Government, 1969). The study recognized that tractors enabled earlier plowing but found that while some farmers did start plowing a little earlier, this did not result in any significant change in existing cropping patterns. Many farmers preferred to utilize their tractor to delay land preparation until adequate rainfall was assured. As a result they followed basically the same cropping pattern as farmers using animals.

S.S. Johl of the Punjab Agricultural University, using 1967-70 data from India's Punjab region, found that a 79 percent increase in tractor use led to a 52 percent reduction in bullock use, a 20 percent increase in labor inputs and a nine percent increase in cropping intensity. His results are summarized in Table V. Using eight hour days to measure the change in inputs; as tractor use increased by approximately one day per acre, bullock use declined by five days and labor use increased by ten days.

The studies surveyed in this section suggest that tractorization alone probably does not increase cropping intensity by more than ten percent on the average. The impact of other types of mechanization on cropping intensity have not been investigated carefully. The introduction of irrigation pumps and tube wells in India and Pakistan is the possible exception. These appear to have resulted in

TABLE IV: CROPPING INTENSITY OF MECHANIZED vs NON-MECHANIZED FARMS

Crop	Tractor Farms % * (1)	Bullock Farms % (2)	Ratio Tractor to Bullock (3)=(1)÷(2)
	Philippines (1964-65) 1/		
Rice	200	162	1.23
	Pakistan (1966-70) 2/		
Various	119	111.5	1.07
	India (1972) 3/		
Various			
Zone I	159	162	0.98
Zone II	127	134	0.95
	India (1971) 4/		
Various	120	114	1.05

Note: *Cropping intensity is measured by the total number of hectares planted per year divided by the number of arable hectares. Thus, double cropping of all arable hectares results in a cropping intensity index of 200 while an index of 162 indicates that 62% of arable land was double cropped.

Source: 1/ Alviar, undated study.
2/ McInerney and Donaldson, 1973.
3/ Parthasarathy and Abraham, 1974.
4/ Donde, 1972.

a greater increase in cropping intensity than the introduction of tractors. The introduction of grain harvesting and drying equipment theoretically could enable more intensive cropping in some areas but there is not enough field research to determine if the theoretical opportunities are realized in practice.

VI. Mechanization and On-farm Employment

In microeconomic theory, output is viewed as a function of inputs which frequently are assumed to be interchangable. Rice production, for example, can be viewed as a function of land, labor, and capital inputs. In theory, if capital inputs are increased with land and labor held constant, output should increase. Alternatively, if output and the land input are held constant while capital is increased, the rational producer would reduce labor inputs. This theoretical model frequently is the starting point in a chain of reasoning which leads to the conclusion that mechanization will increase unemployment. Various approaches have been taken to support the alternative conclusion that mechanization, in fact, increases employment. One approach is to emphasis the potential off-farm employment effects of mechanization. Here it is argued that labor inputs are required to build and maintain the machines and that these inputs may more than offset the reduction in farm employment. A second approach is to treat mechanization as a shift in the production function. Machines are viewed as completely new inputs which embody the latest technology. They enable farmers to increase yields, utilize land more intensely, and increase labor productivity. The increased yields and more intensive use of land are assumed to increase total employment while at the same time output per unit of labor input is increased.

The data used to support either the "employment" or "unemployment" conclusion is inconclusive. The major difficulty again is the failure to separate the employment impact of mechanization from that of other technological or institutional changes that may occur simultaneously with mechanization. The reliability of much of the employment data is subject to question. The estimates of labor inputs required to complete the same farming operation vary widely between countries as well as between studies in a given country. Part of the differences could be explained if more information were available on the type of land, weather conditions, and particular cultivation methods. Nevertheless, when one study reports labor requirements for land preparation to be five times greater than those reported in another study for the same crop using essentially the same cultivation practices, it appears advisable to use the data with care.

The proposition that mechanization reduces the amount of labor per unit of output is widely accepted but there are only general estimates of rate of technical substitution of farm machinery for labor. The available data on labor use per hectare, with and without mechanization, could be used to estimate changes in labor input per unit of output if it is assumed that mechanization has no yield effect. Most estimates of labor use per hectare fail to quantify accurately the degree of mechanization used. As a result, it is impossible to estimate, from available data, the extent to which particular machines or implement combinations actually substitute for labor per unit of output.

TABLE V: CHANGES OCCURRING AS TRACTOR USAGE INCREASED IN FARMS IN THE PUNJAB, INDIA

Year	Tractor Usage (hr/acre)	Bullock Usage (hr/acre)	Labor Used (hr/acre)	Intensity of Cropping 1/
1967-68	9.6	76	408	132
1968-69	12.7	48	443	135
1969-70	17.2	36	490	144

Notes:
1/ Ratio of gross cropped area to size of land holdings.

Source:
Results of a study by S.S. Johl reported by Drew and Bondurant 1972. Table adopted from Stout and Downing, 1974.

A number of rough estimates of the "labor replacement" impact of machines have been developed, however, which provide "rules of thumb" for estimating the employment impact of farm equipment in specific localities.

For example, using farm management surveys, Billings and Singh estimated the per acre labor replacements of different mechanical devices used in the Punjab, India as follows:

1. Pumpsets at 1/4 the man-hours required with a Persian wheel,

2. Wheat threshers at 1/4 the man-hours as indigenous methods,

3. Tractors at 1/5 of man-hours required using bullocks,

4. Reapers at 1/5 the man-hours needed with traditional methods, and

5. Corn shellers at 1/7 the labor formerly required (Billings and Singh, 1970).

Using monthly estimates of labor replacement of various levels of mechanization on an irrigated 10-acre farm in the Punjab, they found that the introduction of high yielding grain varieties (HYV) produced with conventional power sources in 1968-69 would have increased labor use by six percent. HYV with pumpsets would increase labor requirements by only two percent while the use of HYV, pumpsets, wheat threshers, cane crushers, corn shellers, tractors, and reapers would reduce total labor requirements by nearly six percent. Projecting the impact of mechanization to 1983-84, HYV with a high level of mechanization resulted in a 17 percent net reduction in labor use compared to using conventional farming methods with HYV. These results are summarized in Table VI. They illustrate the substantial employment impact of the HYV. Wheat threshers are estimated to cause the largest reduction in employment in the short-run while the introduction of tractors has the greatest long-run impact.

There appears to be wide agreement that the long-run effect of farm machinery on agricultural employment is likely to be substantially greater than the short-run effect. During the early stages of mechanization only a few operations are mechanized. Water pumping, land preparation, and grain threshing are frequently the first operations mechanized. The employment impact of this mechanization may not be readily apparent in the short-run because of other technological changes such as the introduction of HYV taking place simultaneously. Over the longer run, however, tractors begin to be used for additional mechanization. The long run impact of farm mechanization is clearly illustrated by the United States experience. Labor requirements for wheat production in the United States fell from 160 man-hours per hectare in 1830 to 6 in 1930 (Abercrombie, 1972). For agriculture as a whole, labor input per hectare was reduced by two-thirds between 1896 and 1953, while machinery input per hectare rose more than sixfold (Kendrick, 1961).

TABLE VI: CHANGES IN THE DEMAND FOR LABOR AS A RESULT OF MECHANIZATION IN INDIAN PUNJAB

Level of Technology	Estimated 1968-69 (%)	Projected 1983-84 (%)
Conventional	100	100
1. with HYV	106	113
2. with pumpsets	102	103
3. with wheat threshers	96	96
4. with cane crushers	95	94
5. with corn shellers	95	92
6. with tractors	94	86
7. with reapers	n.a.	83
Net change 1/	-6	-17

Notes:

1/ Conventional minus line 6 for 1968-69.
Conventional minus line 7 1983-84.

Source: Billings and Singh, 1970.

Estimates of the labor replacement impact of tractors vary widely. McInerney and Donaldson (1973) estimated that the use of four wheel tractors in Pakistan during 1966-70 reduced labor use per cultivated hectare by some 40 percent, resulted in 4.2 tenant families replaced per farm, and a net overall destruction of about five jobs per tractor. Abercrombie, using data for Colombia, noted that the impact of tractors on employment varies with farm size. He estimated that as many as 18.9 workers could be displaced per tractor on the average for farms in the 50 to 199 cultivated hectares range. For farms with over 200 cultivared hectares, however, the substitution ratio drops sharply to 2.3 workers per tractor (Abercrombie, 1972). For Colombia overall, Abercrombie estimated that the introduction of one tractor resulted in a reduction of average labor requirements for major field crops of 5.7 man years. This compares with 4.1 man years in Chile and 6.8 man years in Guatemala. The smaller reduction in

Chile than in the other two countries may be accounted for by the higher proportion of irrigated crops and greater use of animal power in Chile compared to Guatemala where very little animal power is used in traditional agriculture. Abercrombie's estimates are based on labor requirements rather than actual use. Therefore, they illustrate the potential impact of tractorization rather than actual changes in rural employment during a particular time period.

Several researchers have noted that increased use of tractors appears to reduce employment less on large farms. In some cases, large farms may find it profitable to maintain more workers than needed most of the time in order to have adequate labor supplies during peak employment periods. Other researchers report a larger labor replacement effect for tractors used on large farms. What may happen is that when tractors are first introduced on large farms, workers are provided other on-farm employment opportunities but that the nubmer of new opportunities diminish rapidly with increased mechanization.

The employment impact of mechanization depends partly on the mixture of crops grown. Differences in labor requirements for major crops produced with and without mechanization in several Latin American countries are presented in Table VII. Mechanization appears to reduce labor requirements for potatoes by only 6 to 19 percent compared to a 50 to 90 percent reduction for wheat. The overall average for the five crops and four countries is approximately a 50 percent reduction in labor requirements with mechanization (Abercrombie, 1972). Again, actual labor replacement may be less than the potential estimated replacement. Nevertheless, the potential reduction in labor use appears large enough to justify the conclusion that mechanization generally will reduce employment per hectare as well as per unit of output other things remaining constant.

It has been suggested that this conclusion, while applicable to large four wheel tractors, does not apply to small two wheel tractors (Javed Hamid, 1973). Basically, the argument is that small two wheel tractors replace animals not farm workers while large tractors presumably replace both. Farm survey data for the Philippines does not support this conclusion. Based on a small sample of rice farmers in Nueva Ecija, Philippines, Bautista, and Wickham (1974) estimated labor inputs of primary and secondary tillage to be 7.4 man days per hectare using carabao compared to 4.0 days for farmers using small two wheel tractors. This represents a 46 percent reduction in labor use for land preparation alone. The farmers surveyed recognized very little yield difference after using tractors compared with the period when carabaos were used. They did, however, observe less weed competition on land prepared by tractor but there was no indication that this lowered labor inputs for weeding. The labor replacement effect of two wheel tractors was only slightly less than that of four wheel

TABLE VII: LABOR REQUIREMENTS, WITH AND WITHOUT MECHANIZATION, IN SELECTED LATIN AMERICAN COUNTRIES

	Corn	Rice 1/	Beans	Potatoes	Wheat
	(man-days per hectare except as noted)				
Chile 2/					
a. Without Mechanization	60	48	70	75	26
b. With Mechanization	35	33	50	65	10
c. (b) as % of (a)	58	69	71	87	38
Colombia					
a. Traditional	49	71	62	125	32
b. Modern-non-mechanized 3/	78	93	82	193	63
c. (b) as % of (a)	159	131	132	154	197
d. Modern Mechanized	30	36	18	156	7
e. (d) as % of (b)	38	39	22	81	11
Guatemala					
a. Human Energy Only	56	103	57	162	103
b. Human and Mechanical Energy	44	54	44	153	47
c. (b) as % of (a)	79	52	77	94	46
Paraguay					
a. Without Mechanization	48	85	--	--	16
b. Semi-mechanized	8	26	--	--	6 4/
c. (b) as % of (a)	17	30			38

Notes:

1/ Irrigated rice.

2/ Data for irrigated crops.

3/ Theoretical situation of improved agriculture without mechanization.

4/ Fully mechanized.

tractors. Their estimates of the changes in labor use resulting from the rental of four wheel tractors are presented in Table VIII. Total labor use was reduced by 52 percent. Family labor inputs declined by 54 percent while hired and exchange labor inputs fell 38 percent as a result of renting tractors.

The impact of small hand tractors on employment also depends partly on the type of crop grown. Banta used field experiments to compare labor use with three levels of power inputs; hand labor, carabao, and two-wheel tractors. His results are shown in Table IX. For rice production the use of carabao required only 59 percent of the labor inputs of hand operations while small tractors required only 30 percent as much labor as hand cultivation and only 51 percent the labor inputs required when using a carabao. In the production of sweet potatoes the use carabao had an even greater effect on labor use than did a hand tractor. When cowpeas and corn were intercropped, carabao required only 46 percent of the labor input of hand operation while two wheel tractors required only 34 percent as much labor as hand cultivation methods. The substitution of animal power for land labor appears to result in an even greater reduction of small tractors for animal power.

Additonal data on the employment impact of small tillers used for rice production in the Philippines is presented in Table X. The labor input used in land preparation is nearly 73 hours per hectare when carabao are used for both plowing and harrowing (technique T5) and only 34 hours per hectare when small tillers are used for both operations (technique T3). Small tillers reduce labor inputs by over 25 percent when used only harrowing and by over 50 percent when used for both plowing and harrowing.

Estimates of a fifty percent reduction in labor requirements are also reported in other studies. Bose and Clark (1969) using field survey data for Pakistan reported that, "(in) interviewing farmers in the Punjab who have mechanized, we received a remarkedly consistent response that the labor force per acre had been reduced about 50 percent from the pre-mechanization period." McFarguhar and Hall (1970) using data on cotton production in Uganda reported a 57 percent reduction in man-hours per acre for mechanized vs hand-hoe cultivation.

These estimates provide little information on the changes in crop production patterns or in the composition of the labor inputs which frequently take place simultaneously with mechanization. Some studies report a reduction in family labor inputs and an increase in use of hired labor. Others report reductions in both family and hired labor inputs and in some cases family labor inputs reportedly increase while hired labor is reduced. In some countries, machine rental services are widely available, in other cases farmers own their own

TABLE VIII: IMPACT OF USE OF FOUR WHEEL TRACTORS, NUEVA ECIJA, PHILIPPINES, 1972-73

	Days Per Ha 1/	Percentage
1. Labor Use Before Renting Tractors	7.3	
2. Labor Use After Renting Tractors	3.5	
3. (2) ÷ (1)		48
4. Family Labor Used Before Renting Tractors	9.6	
5. Family Labor Used After Renting Tractors	4.4	
6. (5) ÷ (4)		46
7. Hired & Exchange Labor Before Renting Tractors	3.1	
8. Hired & Exchange Labor After Renting Tractors	1.9	
9. (8) ÷ (4)		62
Work Done With Labor Saved by Using Tractor Services (% of farms)		
a. Fix and clean bunds		57
b. Cleaning before Final Harrowing		27
c. Work on other farms for pay		1
d. Non-farm work		15
TOTAL		100

Notes:

1/ Unweighted averages of wet and dry season data for farmers renting four-wheel tractors.

Source: Bautista and Wickham, 1974.

TABLE IX: LABOR USE WITH THREE POWER SOURCES FOR SELECTED CROPS IN THE PHILIPPINES, 1973

	Hand Labor (1)	Carabao (2)	Hand Tractor (3)	Employment Impact: Carabao (2)÷(1) (%)	Hand Tractor (3)÷(1) (%)	Tractor vs Carabao (3)÷(2) (%)
	(Hours per hectare)					
Rice						
Labor 1/	660	390	200	59	30	51
Carabao 2/		65				
Tractor 3/			25			
Sweet Potato						
Labor	980	420	370	43	38	88
Carabao		245				
Tractor			15			
Cowpea & Corn						
Labor	1140	530	390	46	34	74
Carabao		130				
Tractor			45			

Notes:

1/ Labor time in hours per hectare.

2/ Carabao time in hours per hectare.

3/ Tractor time in hours per hectare.

Source: Gordon R. Banta, 1973.

TABLE X: LABOR INPUTS USED IN LAND PREPARATION, NUEVA ECIJA, PHILIPPINES, 1973

Land Preparation Technique 1/	Labor Input in (hr/ha)			As Percent of T5	Mean Yield (MT/ha)
	Plow	Harrow	Total		
T1	5.09	40.02	45.11	62	3.97
T2	7.60	40.59	48.19	66	4.00
T3	13.38	20.56	33.94	47	4.14
T4	33.99	19.84	53.83	74	4.01
T5	32.28	40.34	72.62	100	3.94

Notes:

1/ Data apply to medium hardpan soil conditions during the 1973 wet season.

T1 - Large tractor plowing and carabao harrow.
T2 - Large tiller plowing and carabao harrow.
T3 - Small tiller both plow and harrow.
T4 - Carabao plow and small tiller harrow.
T5 - Carabao both plow and harrow.

Source: Orcino and Duff, July, 1974.

tractors and apparently are reluctant to rent them or undertake custom work. These differences appear to be the result of differences in institutional structures. The introduction of tube wells and irrigation pumps frequently increases the opportunities for multiple cropping and gradually results in changes in cropping patterns. Where tractors actually replace bullocks, some land formerly devoted to fodder crops may be devoted to other crops. In a few cases, the demand for various crops appears to shift rapidly either just prior to significant changes in the rate of mechanization or during the early stages of mechanization. This results in a supply response that involves changing the composition of production. Many of the production changes probably would occur with no changes in mechanization but mechanization may enable the changes to take place more rapidly either for technical reasons (increased water availability, for example) or by inducing changes in relative factor prices.

The factors causing the changes which take place simultaneous with mechanization are difficult to identify and in many cases nearly impossible to quantify. Different opinions about the direction of the cause-effect relationships can lead to substantial differences in conclusions concerning the "effects" or the "value" of mechanization. This can be illustrated using the data in Table XI on the influences of tractors on employment in India. These data are based on a study of 76 farms having 79 tractors in the Dhulia district in Hamharashtra, India (Donde, 1972). The increases in employment per hectare ranging from 10 to 32 percent reportedly are "the result of tractor mechanization" (Stout and Downing, 1974). Much of the employment increases could, however, be attributed to the changes in farm structures which occurred simultaneously with mechanization. These include:

1. 50 percent of the wasteland was reclaimed,
2. net irrigated area increased by 24 percent,
3. the double cropped area increased from 14 percent of the net sown area before tractors to 20 percent after,
4. the cropping pattern changed towards more intensively grown crops after tractors were introduced.

The question is, "Could these changes have taken place (or would they have taken place) without the introduction of tractors?" Were tractors essential to reclaiming the wasteland? Did tractors cause a change in cropping patterns or did the changes reflect changes in relative prices and costs? Were tractors needed to increase the irrigated area? Was the increase in area double cropped the result of tractors or due to the increased availability of irrigation water? If one concludes that tractors "caused" the changes in farm structures, then it follows that the introduction of tractors did in fact "result in an increase in labor inputs." Such a conclusion certainly is debatable.

It appears that much of the data presented to support the argument that mechanization leads to an increase in farm employment is misinterpreted and reflects a failure to separate the employment effect of machinery from that of other technological changes occurring simultaneously with mechanization. Theoretically, large tractors (30 to 90 hp) could reduce labor inputs by at least 80 percent and small two-wheel tractors (7 to 15 hp) probably by at least 60 percent compared to use of bullocks. In practice, it appears that in grain production, large tractors probably reduce labor inputs per hectare by 40 to 50 percent and small tractors by 30 to 40 percent. The introduction of tube wells with irrigation pumps appears to be the only case in which mechanization may have a significant positive effect on employment either through higher yields or more intensive multiple cropping.

VII. Mechanization and Off-farm Employment

An assessment of the total employment effects of mechanization must take account of the employment generated by the manufacture, distribution, maintenance, and repair of farm equipment. It is often argued that such off-farm employment goes a long way towards offsetting any displacement of agricultural labor possibly caused by mechanization. Estimates of the off-farm employment effects of mechanization are even less precise than the on-farm estimates. Nevertheless, the limited available evidence suggests that the off-farm employment resulting from increased mechanization is rather small relative to the loss of on-farm employment.

Abercrombie's estimates of employment in agricultural machinery manufacture, distribution, maintenance, and repair in LAFTA countries are presented in Table XII (Abercrombie, 1972). The estimates admittedly are very rough but, if anything, probably overestimate total employment. For the eleven LAFTA countries in 1968 total employment in agricultural machinery and related activities was less than 150,000. Although these jobs are at a much higher productivity and income levels than agricultural jobs, their number is almost insignificant in the over-all employment situation. They represent only 0.2 percent of total employment and approximately 0.5 percent of the number of persons employed in agriculture.

TABLE XI: INFLUENCE OF TRACTORS ON EMPLOYMENT IN INDIA

	Tractor Farms (1)	Bullock Farms (2)	Difference (1)-(2)	Difference (1)÷(2)
	(man days/ha.)			%
Mazaffarnagar, U.P				
Casual labor employment	91	69	+22	132
Ferezepur, Punjab				
Employment on tube-well farms	104	88	+16	118
Employment on canal-irrigated farms	51	46	+ 5	110

Source: Donde, 1972 as reported by Stout and Downing, 1974.

TABLE XII: ESTIMATED EMPLOYMENT IN AGRICULTURAL MACHINERY MANUFACTURE, DISTRIBUTION, MAINTENANCE, AND REPAIR IN LAFTA COUNTRIES (1968)

Country	Domestic Manufacture		Intermediate Products	Ancillary (a)	Total (b)
	Tractors	Other			
	(1000 persons employed)				
Argentina	5	15	7	20	47
Brazil	2	17(c)	6	16(d)	41
Mexico	1(e)	7	2	14(d)	24
Other	--	5(c)	2	21(d)	28
TOTAL	8	44	17	71	140

Notes:

a. Based on estimate of 34 percent purchases on the internal market in Argentina.
b. Total includes distribution, maintenance, and repair of agricultural machinery including imports.
c. Applying the average of the Argentina and Mexico ratios to production.
d. Applying the Argentina ratio to total sales.
e. Rough estimate.

Source: Abercrombie, 1972.

Using data for Brazil and Argentina, Abercrombie estimated that an investment of up to US $10,000 is required to create one job in tractor manufacturing which will produce two to five tractors each year. With some additional investment, one further job may be associated with the distribution of these tractors and the maintenance and repair of the existing stock. Another one-third of a job may result from backward linked industries. This is only 2.3 non-agricultural jobs resulting from the production of two to five tractors annully, or one such job from the production of 0.9 to 2.2 tractors. Each tractor has the potential to reduce farm employment by five man years during each year of operation. Assuming that tractors last ten years, each off-farm job generated by tractor production potentially could displace from 4.5 to 11.0 agricultural workers annually over the ten year tractor lifetime. In practice, each tractor probably does not reduce employment initially by more

than half of its potential. Even so, during the early stages of mechanization, each man-year of non-agricultural employment associated with mechanization would reduce on-farm employment by 20 to 50 man-years over a ten year period. In Abercrombie's judgement, the lower limit on the replacement ratio for Latin America is approximately 1 to 30.

Similar conclusions apply to the local manufacture of small two-wheel tractors in the Philippines. Local manufacturers of small two-wheel tractors (7.5 hp) estimate that it requires from 5 to 20 man-days to produce and assemble a small tractor depending on the type of equipment available to the plant and the size of the production run. Using an average of 12.5 days per small tractor assembled, a production worker would produce approximately 20 small tractors annually. Backward linkages are relatively small in this case because a large part of the material for the tractors is imported. Labor requirements to distribute and service the tractors probably are not more than two man-years per 20 tractors. In this case, each man-year of non-agricultural employment results in 6.7 small tractors which normally would remain in production for at least 5 to 7 years. The on-farm employment effects of these tractors can be estimated using the data from two IRRI studies. Orcino, using a small survey of 45 hadn tractor users in Laguana (Philippines), estimated the average 7.5 hp tractor was used approximately 600 hours annually in 1970 (Orcino, 1972). Banta's field experiment data in Table IX indicate that 25 hours of tractor time are required to produce a hectare of rice and that the use of hand tractors for rice production reduced labor requirements by 190 hours per hectare (Banta, 1973). Using these estimates, the hand tractor used 600 hours could cultivate 24 hectares of rice and would reduce labor requirements by 4560 hours. Assuming 225 eight hour work days annually, each small tractor would reduce labor requirements by 2.5 man-years annually or approximately 12 to 18 man-years over a five to seven year period. If 6.7 tractors are produced and maintained per man-year of off-farm employment then the result is a total reduction of 80 to 120 man-years of on-farm employment in rice production per man-year of employment with cowpeas, each year of employment off-farm to produce small tractors would reduce on-farm employment by 35 to 50 man-years over a five to seven year period.

These results, though based on very different data than used by Abercrombie, lead to very similar conclusions; as a minimum, a man-year of non-agricultural employment in the production, sales and service of tractors (whether large or small) reduces on-farm employment by 20 to 30 man-years.

The estimates for both South American and the Philippines are very rough. Nevertheless, even if the off-farm employment per tractor was doubled and the on-farm reduction in employment reduced by 50 percent, the off-farm employment created would still be far short of off-setting the reduction in on-farm employment.

VIII. Approaches to Increasing Power Available to Agriculture

By nearly any standard of comparison, the amount of power (human, animal and machine) available to agriculture in developing nations is low. More intensive cultivation will require increases in the availability of agricultural power and/or more intensive and effective utilization of available power sources. The available data suggest that agricultural mechanization is increasing throughout the world, although relatively slowly in many countries and with wide regional differences in the rate of mechanization within countries. The high rates of rural unemployment and underemployment reported in many LDC's suggest that available manpower is not fully utilized. Whether this is because the rate of mechanization has been too fast or too slow has never been answered adequately for any particular country and probably cannot be answered in general.

Population growth in most countries increases human power availability by two to three percent annually. This adds very little to net power availability. A man develops approximately 0.1 HP using food as his energy source. Where unemployment and underemployment rates are high, the additional manpower is not fully utilized. When utilized with traditional technology, man consumes 10 to 20 percent of his food energy output and uses much of the the remainder to maintain his family. Furthermore, in most countries the marginal physical productivity per available human horsepower is likely to decrease as the man/land ratio increases and poorer quality land is brought into production. Thus while increased manpower may result in more intensive cultivation, it is unlikely to result in any substantial increases in per capita food production.

In some areas, particularly in parts of Africa, increases in the number of draft animals may be an appropriate way to increase power available to agriculture. Draft animals (cows and bullocks) can provide up to 0.6 HP and can utilize energy from grasses and food by-products not used for human consumption. In traditional agricultural systems land held in fallow frequently provides the feed requirements of animals. When only small amounts of land are held fallow, grain by-products and grasses from field margins provide most of the required livestock feed. The feed costs for draft animals used in traditional agricultural systems are fairly low but the opportunity costs of fallow land used for animal feeds may increase substantially with the introduction of modern technology. Where unemployment and underemployment rates are

high, the immediate labor costs of caring for draft animals also are relatively low. Draft animals are difficult to maintain, however, in locations where water is scarce, annual rainfall is extremely variable, or livestock diseases are common.

Under favorable conditions available animal power could be doubled every ten years or so. Where most arable land is already in production and human population is doubling every 25 to 30 years, increasing animal numbers does not, however, appear to be a viable long-run approach to increasing agricultural power. Furthermore, there is a point at which the maintenance cost of keeping high levels of animal power per hectare becomes prohibitive. The introdution of modern agricultural systems increases the opportunity cost of the land and labor required to maintain animals and lowers the relative cost of fossil fuel power sources. Thus programs to introduce modern production technology and to increase draft animals numbers become increasingly non-complementary as the availability of unused arable land declines. Programs to increase draft animal numbers, therefore, should be viewed as intermediate term programs which may be appropriate in situations where available agricultural power is below approximately 0.2 HP per hectare, unused arable land is relatively abundant, water supplies are adequate and reliable, and livestock diseases are not a serious problem.

In those countries where draft animals are used widely, programs to up-grade the quality of animals, improve livestock management, and develop more effective animal power implements probably would result in better utilization of available animal power. There exists very little information, however, by which to judge the potential of such programs. It seems unlikely that they would increase the rate of return on the average farmer's investment in draft animals by more than ten to twenty percent. Furthermore, such programs would have to reach a large number of small farmers in order to have a significant total impact. Thus, animal power improvement programs probably would be of greatest value when included as part of a more general technology improvment package designed for small farmers using draft animals.

Increased mechanization appears to be the only viable means of significantly increasing available agricultural power in most countries over the long run. It seems likely that liquid fossil fuels will continue to be the lowest cost energy source for machines providing mobile power; at least for the next twenty to thirty years. Conservation of liquid fossil fuels will require increased use of solar energy, gravity systems, and wind power as well as more complete and efficient utilization of agricultural by-products. Non-fossil fuel energy sources can be most readily used for stationary power units. Rice hull burners for grain drying and windmills to pump irrigation water are examples of stationary power

units utilizing non-fossil fuel energy.

Most government programs to encourage farm mechanization during the 1960's emphasized the introduction of tractors. These programs, which frequently were supported by international lending agencies, have received more thorough evaluation than most other types of mechanization programs. Many of the tractor mechanization programs have been judged to be failures in the sense that estimated social costs exceeded social benefits. The tractorization studies have provided estimates of labor replacement but little empirical data on actual unemployment created by the introduction of tractors. They do, however, indicate that large farmers have usually benefited more than small farmers from government programs to subsidize tractor purchases.

The conclusion that tractorization programs have seldom increased social welfare has not led to a rejection of mechanization programs in general. It has, however, led to various proposals which place more emphasis on minimizing unemployment effects and improving income distributions.

One approach is to promote selective mechanization. That is, to mechanize those operations which will reduce costs, have the least effect on employment, and the greatest effect on output. Selective mechanization hopefully would improve working and living conditions in rural areas thus making rural living more attractive and reducing migration to urban areas (Stout and Downing, 1974). The emphasis is on increased productivity of labor while maintaining employment per unit of land area. Those operations where accuracy and timing are important for increased yields, for example, may be selected for mechanization provided they reduce per unit production costs and increase labor productivity without substantially reducing employment.

A second approach, sometimes referred to as fractional mechanization, focuses almost exclusively on the small farmer. It is essentially a "small is beautiful" approach. Tractors are viewed as "lumpy inputs" which frequently are inappropriate for small farmers because their services are difficult to allocate to small land units. The alternative is to develop and introduce small machines which will replace animals rather than people. Small two-wheel tractors are an example (Hamid, 1973).

A third approach is to promote appropriate mechanical technologies. This approach views the mechanization of agriculture as a continuous and inevitable process in economic development but one whose speed and direction can be altered by public policies and programs. The criteria used to define what is "appropriate" depend on a nation's goals. If a nation's development program emphasizes equity, employment and production, then particular agricultural implements would be considered appropriate if:

1. their use is profitable for a relatively large proportion of the nation's farmers,

2. they can, to a large extent, be produced locally,

3. they make the maximum possible use of domestically available resources such as energy, materials, and labor skills, and

4. they provide more effective and timely operations which enable farmers to increase output either through increased yields or more intensive use of their land resources.

Obviously, what is "appropriate" for one country may not be appropriate for another, or even for the same country at a later stage of development. Less obvious, but perhaps more important, is the implication that appropriate mechanical technologies, or at least the most appropriate ones, may not yet be available to many countries.

The appropriate mechanical technologies approach appears to have wide support. It reflects a sensitivity to unemployment and income distribution problems, an awareness of the technical limitations of small machines, and focuses on a few key aspects of the social and technical infrastructure required for successful mechanization programs.

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