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AGRO-MECHANICAL TECHNOLOGIES IN LATIN AMERICA: A SURVEY OF APPLICATIONS IN SELECTED COUNTRIES

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PREFACE

This study of agro-mechanical technologies reflects the Inter-American Development Bank's concern for the use of technologies which are appropriate to conditions in the developing member countries. Bank policies in this area include both ensuring that appropriate technologies are utilized in Bank financed projects, and obtaining and disseminating information on the subject.

Agro-mechanical technologies are of particular interest because while they can play a positive role in increasing output, there is a potential for labor displacement if inappropriate technologies are widely applied. Since a large proportion of the Latin American labor force is employed in agriculture (about forty percent) and productive employment opportunities in urban areas are limited, the technological alternatives must be carefully considered. Another concern of the study is the extent to which improvements in mechanical technology are designed to meet the needs of small farmers and are available to them.

Because the mechanization issue has not been analyzed in Latin America to the extent that it has in other developing regions, this study was planned to be executed in two stages. This report represents the first stage effort, which aims at describing the extent of agricultural mechanization in selected Latin American countries and variations in mechanical technology in the region. It also deals with analytical and policy questions in a tentative manner. The proposed second stage of the study will deal with these issues more definitively and in greater depth.

The study was carried out under a consulting arrangement with L. Harlan Davis, Director of International Programs and Studies of the University System of Georgia. Dr. Davis collaborated with Rex L. Clark, Associate Professor of Agricultural Engineering and J. Michael Patrick, Agricultural Economist, both with the University of Georgia. Supervision of the study was the responsibility of James R. Taylor of the Agricultural Economics Section of the General Studies Division.

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I. Introduction

A. The Problem

The optimism of the 1960s portrayed by the accomplishments of the Green Revolution has given way to growing pessimism. There are doubts concerning future production trends, and problems of unemployment and inequitable income distribution are widespread. Although the outlook in most of Latin America is not nearly so serious as it is for many African and Asian countries, meeting expanding food and fiber production requirements in the region continues to be a matter of critical concern.

In 1976 Latin America as a whole became a net food grain importer, after being a net food grain exporter in the early 1970 (Burki & Goering, 1977, p.15). In recent years bad weather has been just one of the factors adversely affecting agricultural production. Higher fertilizer prices have also been influential. At the same time, demand continues to rise, fueled by a rapidly growing population and rising per capita incomes.

Another pressing problem in Latin America is open and disguised unemployment. While a rapid growing industry in many urban areas has been able to absorb a large number of workers, this sector has not fulfilled earlier employment promises. Recent studies indicate that while the manufacturing share of nation output in Latin American countries has risen from approximately 17 percent to 24 percent during the 1940-1970 period, its share of employment remains almost constant at 14 percent (Ramos 1974; ILO, 1977). Said differently, technological advances in the manufacturing sector of many Latin American countries in the past three decades have generated few new jobs. Similar employment trends are occurring in the agriculture sector; this point will be discussed in greater detail later in the report.

FAO estimates that "unused labor" in the region may be as high as 28 percent of the labor force in 1970 (FAO, 1973). Thorbecke (1970) says that unemployment and underemployment together may reach 25 percent, over half which is in the rural sector. The problem is more serious in some countries than others; it is acute in certain regions within countries. The economic and social effects of unemployment are many--whenever resources are not used to their maximum capacity, production is sacrificed and income is foregone. Further, unemployment breeds political unrest, anomie, and even violence.

A third pressing issue in Latin America is the great disparity in income and wealth patterns. Despite the Alliance for Progress which in 1961 promised a concerted and massive effort on this problem, it has continued to persist. In the countryside of most Latin American countries the best land is still in the hands of a few. Ownership of factories and plants which have grown rapidly over the region in recent years is highly

concentrated. High production growth rates in selected industries have accentuated income disparities. For example, Baer's (1973) research shows that in Brazil income distribution has become highly skewed since 1970 and the minimum wage, expressed in constant terms, has changed little since 1966. A recent study of the Colombian economy shows that large sections of the population have realized little benefit from recent annual GNP growth rates exceeding five percent (ILO, 1976). The same study goes on to show that the poorest one-third of the population is not much better off than it was in the 1930s.

Designing rural development programs to address the problems of food supply, unemployment, and income and wealth disparity is a challenging task for planners and policy makers in Latin America. It is complicated by the fact that emphasis in one direction can aggravate the situation in another. A program to increase food and fiber production might have small effects on employment and income distribution; one that addresses employment and income problems might not contribute to food production.

Among the broad options for increasing food supply are:

1. Bringing new areas into cultivation through the expansion of the agricultural frontier; and

2. Increasing intensity of production on presently cropped areas thereby raising productivity per hectare.

Except for a few countries, most notably Brazil, option one is not viable. Even there studies show the useful frontier is rapidly diminishing in most settled areas. In Bahia, a state about the size of France, the potentially useful frontier could be fully incorporated into crop and animal production by the late 1980s (Davis, 1975).

Option two, however, is viable in most of Latin America. Although no systematic study of the situation is available, there is a substantial difference between potential and actual farm yields in most countries. It might be argued that the most expeditious way to raise productivity would be to undertake a massive program of technology development, diffusion, mechanization, credit and marketing improvements for large commercial farms. Such a strategy, however, could well aggravate problems of unemployment and income distribution, particularly in the countryside.

On the other hand, if programs designed to raise land and labor productivity were targeted to Latin America's small farmers, it might be feasible to increase food production as well as improve their employment and income opportunities. Raising small farm productivity, however, is a challenging proposition. Innovative efforts have been and are being tested throughout the Hemisphere, although no major breakthroughs can be reported. In some instances there has been limited success with transferring known technologies and providing complementary inputs and services to small operators (Davis, 1974). But for the most part the problem seems to be more complicated.

B. Objectives of the Report

The question has been raised by the Inter-American Development Bank, where and how does agro-mechanical technology fit into agricultural development in Latin America, and especially small farmer development strategies? With a recently adopted Appropriate Technology Policy (November 1976), and a continuing interest in raising small farm productivity, the purpose of this report is to learn more about the potential for agro-mechanical technology on small farms in Latin America for purposes of guiding Bank policy and establishing lending possibilities. For this purpose, agro-mechanical technology is defined here as any set of power units (human, animal or motorized) and associated equipment, for use in field operations from land preparation to harvest. 1/

The objectives of this report may be summarized as follows:

1. To provide a description of the various agro-mechanical technologies presently used for crop production in the region, with emphasis given to technologies that are appropriate in terms of their labor requirements, acquisition costs, and feasibility for small-scale production units. The description will include technical specifications and data on economic performance (cost and return data for specific crops) when possible. It will cover a limited number of crops, countries and natural regions.

2. To provide an interpretative discussion of the actual and potential role of agro-mechanical technologies. This will include judgements as to their appropriateness, conditions and policies which influence the degree to which they are employed, technologies developed in other regions of the world which might be advantageously transferred to Latin America, recommendations for specific research and development activities intended to create improved mechanical technologies, and other relevant considerations.

As one paper has noted, "of the various technological innovations that have been applied to agriculture in developing nations, none has been subject to as much controversy as mechanization" (Taylor,1977). Careful examination of the literature and field studies in Colombia, Costa Rica, Guatemala and Honduras confirm that controversy over agricultural mechanization in Latin American agriculture does exist. While this report does not seek to resolve the controversy, it does attempt to clarify it through the presentation and interpretation of available information. The goal is to identify key issues concerning mechanization which, through further research, can lead to more informed policy making on this important aspect of agricultural development in Latin America.

The report is organized as follows. Section I is introductory. Section II provides a brief discussion of the issues surrounding the introduction of alternative technologies into developing countries, with emphasis on agro-mechanical technology. The focus is on an interpretation of the actual and potential role of agricultural mechanization, particularly tractors, in resolving the problems of food production, unemployment and income distribution in Latin America. The discussion is based on a review of available literature

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1/ Consideration is also given to storage in Section III.

and information obtained from field work in Colombia, Costa Rica, Guatemala and Honduras. In Section III, a description of selected agro-mechanical technologies currently in use in the region is presented. The emphasis is on primary tillage, although consideration is given to other phases of agricultural production such as harvesting, irrigation and storage. The final section of the report summarizes the findings, sets forth some conclusions and offers recommendations.

C. Small Farmers and Mechanical Technology: Some Considerations and Definitions

Small farmers--a classification. At this point the question as to what is meant by small farmers is raised. Agriculture in Latin America is very heterogenous. Among others it varies by tenure system, farm size, crops raised, topography, climate, soil types, location of farms, social background of farmers, and the political-economic system in which it operates. A classification for the purpose of describing and appraising the potential of mechanical technology could be based on any or all of these criteria. But neither time nor resources permits a complete discussion of all these types. Attention will be restricted to the small producer "sub-family" or "family" units. In the middle sixties, the Inter-American Committee for Agricultural Development (ICAD) defined a sub-family unit as one that would provide effective employment for less than two people while family units provide effective employment for 2 to 3.9 people (Barroclough & Domike, 1966). As the authors of the ICAD studies point out, most of the farmers in Latin America fall into these categories, yet they own or operate a relatively small share of the available farm land. This situation has not changed substantially since their study was completed. While this typology leaves much to be desired small farmers in this report refer to these "sub-family" and "family" classifications.

Mechanical technologies in small operations. There are several stages in the agricultural cycle that may require mechanical technologies:

1. The first of these is clearing the land for agricultural purposes. This step very often involves the removing of heavy forest and brush growth. Also, at times, this might require the removal of stumps or stones. Irrigation ditches and drainage ditches may be constructed in this initial phase and at times it might be desirable to level the topography of the terrain so that it may be irrigated.

2. The second and very often most important step in the agricultural process is tillage. Generally, there is primary tillage in which the ground cover is destroyed by burning, turning over, or otherwise destroying the current vegetative growth. This is the initial process in preparing the seedbed. After the land is plowed for the first time, there may be a secondary tillage in which the land is harrowed or pulverized by a disc-harrow in order to break up the large clumps of soil and to further destroy vegetation. This secondary tillage may at times go through two or three stages, from a disc-harrower to a spike-toothed harrower or other techniques such as a hand rake to evenout all of the clumps. Another secondary form of tillage is that of cultivating the soil after the crops are up to destroy the weeds as well as to aerate the soil.

3. A third phase of the agricultural process involves fertilization and application of other chemical applications to the soil or to the plants. At times, it is necessary to spray a crop several times in order to destroy insects and other pests. Also increasing chemicals may be used to eliminate undesired vegetative growth.

An intermediate stage is irrigation. Often, crop failure may occur if water is not applied when needed. Irrigation can involve a number of rather complex tasks. For example, the water may have to be transported by gravity a considerable distance to the field or it may be necessary to pump the wate from a stream or a deep well. Mechanical technology has a considerable role in the irrigation process.

4. Still another step in the agricultural process is harvesting. There are some crops that can be easily harvested only by hand. This is especially true of many fruits and vegetables. For other crops such as sugar cane, the harvesting must involve the use of some kind of mechanical technology. With others, such as wheat, oats, or corn, there are many levels of technology possible, from the simple scythe in harvesting the small grains to the highly complex corn picker.

5. After the crop is harvested there are several places in the storage process for the use of mechanical technology. One facet is that many crops need to be dried or otherwise processed before they may be stored. Coffee, for example, cannot be stored permanently in the pulp stage and the pulp has to be removed by drying or by a water fermentation process. After processing, most agricultural products require storing. Even hay is stacked in such a way that rain reaches only the outer layer. Other crops, such as small grains, have to be dried before they can be stored to protect them from moisture, rodents and insects. This storage requires some kind of mechanical technology.

6. Finally, transportation services are needed to move the crop from the field to a place where it can be stored or to move seeds and fertilizers to the field.

Thus, mechanical technology has multiple applications on the small farm and any one of these might be the subject of a detailed study. Given its relative importance in production and the potential for the application of mechanical technology. In this report, the emphasis will be placed on the tillage process. While this emphasis does not preclude a discussion and evaluation of other aspects of the agricultural cycle, it does permit the consideration of a manageable problem.

II. Agricultural Mechanization in Latin America: Its Impact on Food Production, Employment and Income Problems

The purpose of this section is twofold. First, issues of concern regarding the choice of technologies available to developing countries are highlighted. Brief consideration is given to the choice among available agricultural technologies. The major focus of this section, however, is on agricultural mechanization in Latin America and its consequences.

A. The Choice of Available Technologies by Developing Countries: A General Discussion

Economic development is a complex process. Not only does it involve an improved allocation of existing resources, if growth is to be sustained over time it requires the development of new resources and methods for increasing resource productivity. Whether the fruits of economic development and growth are shared by a few or many depends upon the social and institutional processes through which economic and political groups influence the allocation of productive resources.

Technology plays a key role in every country's development efforts. Technology, broadly defined, is "knowledge systematically applied to practical tasks". It is embodied in processes and tangible goods, both of the producer and consumer type. The technologies available at a given time and place are determined by activities and policies related to invention, innovation, and technological transfer. Public policy, reflecting private as well as public interests, often influences the choice of technology, by affecting the prices of available resources (factors of production).

Many developing countries are currently concerned with the choice of technology. There is growing dissatisfaction with the performance of technologies transferred from the Western industrialized nations. These technologies are capital-intensive and labor-saving, reflecting the resource scarcities in the industrialized countries.

In general, however, the factor endowments of developing countries reflect a very different distribution of resources--labor is abundant and capital is scarce. An outcome of introducing Western industrial technologies into developing countries may be the inefficient use of available scarce resources, slow economic growth and narrowly-based economic and social development. Consequently, many developing countries are now evaluating alternative technologies in light of their development goals and resource endowments.

According to one analyst, technology appropriate for developing countries

> "....should stimulate economic progress by making optimum use of available resources...should be conducive to social progress by enabling the mass of the population to share the benefits and not just a privileged few...should represent technical progress, measured by improvements over existing methods and not by reference to external standards which may be irrelevant...and should be progressive in a temporal sense, i.e., their characteristics will change over time in response to the society's ability to pay for them and capacity to employ them efficiently. In other words, the concept is dynamic, not static." (Marsden, 1970)

Therefore, in the choice between capital and labor intensive technologies, it is argued appropriate technologies for developing countries should be labor intensive. A number of reasons have been offered to support this contention (Marsden, 1970; Yudelman, 1971; Jackson, 1971; Brannon, 1977). A few are listed below.

1. In developing countries, labor is generally the abundant factor and capital is scarce. Markets are small and linkages between them weak. Income distribution is skewed in favor of a few, unemployment and underemployment are widespread and high. Demand for traditional consumer goods is limited due to the meager purchasing power of 90 to 95 percent of the population.

2. The large-scale production requirements of capital-intensive technology cannot be supported by the small size markets in most developing countries. Consequently many large-scale modern factories will operate well below their capacity. In addition most developing countries cannot afford the level of investment in infrastructure, input industries and market delivery systems which these capital-intensive technologies require to be profitable.

3. Capital intensive technologies often ignore the use of available raw materials of the countries into which they are introduced. And importation of the necessary raw materials or components may add substantially to the total cost for developing countries, both in scarce foreign exchange and employment opportunities at home.

4. The design and processes of capital-intensive technologies are often totally inappropriate for the developing countries' climate or terrain.

5. Adoption of labor intensive technologies can spur broadbased economic and social development. Because of their highly divisible nature, labor intensive technologies lend themselves to the small-scale operations of traditional economic activitiy in developing

countries. The small scale nature of the production units permits them to spread throughout several towns where they can increase the links with the rest of the economy, making fullest use of existing organizations, and managerial and entrepreneural talents.

6. Labor-intensive technologies are likely to stimulate traditional sectors in which the majority of people live and work. The number of productive jobs will increase, and demand for goods and services from other industries will increase. Backward and forward linkages with a variety of industries will generate additional employment opportunities and economic growth.

In sum, the argument is that labor intensive technologies will make better use of developing countries' resources, produce higher rates of economic growth, increase employment opportunities and lead to a more equal distribution of income.

B. The Choice of Agricultural Technologies

Agricultural technologies for increasing production at the farm level can be distinguished by two basic forms:

1. biological-chemical
2. agro-mechanical

Biological-chemical technology is yield-increasing and labor-using, raising total output for a given land base. The new seed varieties and inorganic fertilizer "packages", referred to widely as the "Green Revolution", typify biological-chemical technology.

In contrast, agro-mechanical technology is land-using and labor-saving, raising total output by expanding acreage under cultivation and/or by facilitating multiple cropping patterns. Tractors and complementary equipment for tillage are the types of mechanical technology most often associated with agriculture in developing countries. Other machinery and equipment, however, such as threshers, irrigation pumps, new hand tools, and animal-drawn implements, are important forms of mechanical technology.

Agricultural mechanization programs, particularly those that promote the wholesale introduction of tractors into developing countries, are opposed by some government officials and economists on the grounds they are not appropriate. The most frequently made arguments against agricultural mechanization are:

1. Capital, and in some cases land, is scarce in developing countries while labor is abundant and inexpensive. Agricultural technologies should be adopted that use labor and conserve capital.

2. Land holdings are often fragmented and inaccessible, making the use of some types of agricultural machinery, particularly tractors, difficult and uneconomical.

3. The adoption of agricultural mechinery frequently displaces labor; at the same time jobs outside agriculture are not available for even a small fraction of workers entering the labor market.

4. Agricultural mechanization encourages the large farm to grow larger. Only these farms can obtain the capital, justify the investment and afford to take the risks of experimenting with complex and uncertain technology.

5. Large scale agricultural mechanization encourages landowners to assume more direct personal control of the farming operations, thus converting renter-tenants to sharecroppers and laborers.

6. Agricultural mechanization often contributes to social problems by intensifying already highly unequal patterns of rural wealth and income distribution.

On the other hand, several authors (Shaw, 1970; Eicher, 1970; Abercrombie, 1972; Stout & Downing, 1976) offer a number of reasons for supporting the adoption of agricultural machinery:

1. It may overcome labor shortages due to peak demand periods, immobility of labor, the unwillingness of labor to do some types of work, and the low renumeration of agricultural work;

2. It may reduce production costs;

3. It may increase the rate at which various farm operations can be performed;

4. It may, in conjunction with irrigation, increase total production by making multiple cropping possible;

5. It may reduce crop losses through effective application of pesticides and utilization of on-farm storage and drying facilities; and

6. It may make possible the performance of tasks that cannot be done effectively by hand or with animals.

More specifically, a number of arguments have been made supporting the use of tractors in developing countries. Brannon (1977) has summarized a few of these arguments, five of which are presented below.

1. The lack of power for land preparation may constrain the amount of land that can be planted in a single year. Rapid land preparation with power equipment makes possible multi-cropping and holds considerable potential for increasing employment in the planting, transplanting, fertilizing, weeding, spraying, cultivating, harvesting, transporting and marketing of crops.

2. In areas where virgin or second growth land is available for clearing, shaping and bringing into production, power equipment can be effectively utilized to expand the cultivable area. Particular soil conditions such as clay hard pan may also require power equipment for successful exploitation.

3. Even under "ordinary" conditions, some argue that land preparation with power results in significantly higher output because a superior seedbed is provided and weed competition is reduced.

4. Tractor power does not always substitute directly for human labor; it may substitute instead for animal power. Additional land previously needed for producing animal feed is thus released, though (albeit skilled) human labor to operate the machinery is still required.

5. The argument is also made that new employment generated in the manufacture, sales, distribution and servicing of tractors and other forms of machinery may offset any negative employment impacts that might occur at the farm level.

The degree to which these arguments for and against the use of agricultural machinery, particularly tractors, apply in the Latin American context will be examined later in this and subsequent sections.

C. Role of Selective Agricultural Mechanization

While the displacement of labor in labor-abundant economies has been one of the central arguments against agricultural mechanization, there is evidence that selective mechanization can increase employment opportunities as well as increase food production.

The introduction of new seed varieties and inorganic fertilizers (the Green Revolution), for example, has created a number of production bottlenecks requiring selective mechanization. Experience shows high yielding varieties require accurate placement of seeds and fertilizers, and metering of herbicides and insecticides can only be done accurately by mechanical means. The production of high quality crops requires timely harvesting, threshing and handling, which is often difficult to achieve with traditional implements and methods. Engine-driven pumps are often required to provide water for irrigation to supplement rainfall and promote double and triple cropping. Multiple cropping in turn requires that one crop be removed quickly and a seedbed prepared and another crop planted in a short interval of time, which again, cannot be achieved with traditional implements and methods. Experience in many Asian countries also indicates that the selective introduction of tractors, seeders, harvesters and other agricultural machinery does not result in the automatic loss of jobs, but rather leads to an increased demand for labor (Brannon, 1977).

Review of available literature provides evidence of the impact selective agricultural mechanization has had on food production, employment and income distribution in various developing countries. For illustrative purposes a few cases are summarized below.

The introduction of pump sets in India proved to be labor generating, i.e., labor was required for leveling fields, making channels and bunds, and for diverting and controlling water during the growing season. Because of higher yields and multiple cropping resulting from irrigation, more labor was required for harvest operations (Drew & Bondurant, 1972).

Shambough reported a situation in northeastern Nigeria where a local sorghum is commonly planted by poking a hole in the ground with a stick and dropping a few seeds in. Weather and seasonal conditions are such that the grass grows tall prior to planting time. The factor limiting the amount of sorghum that can be planted is the labor requirement of cutting and removing the grass. Experiments with a tractor-powered rotary mower eliminated this bottleneck and permitted an increase in production and manual labor employed during the remainder of the season (Yudelman, 1971).

Child and Kaneda report that Green Revolution-related production bottlenecks in West Pakistan have generated opportunities for innovation, capital formation and employment at the local level. In their study of West Pakistan agriculture, the authors determined the new fertilizer-responsive dwarf varieties of grain accounted for most of the increase in wheat (79 percent) and rice (61 percent) production from 1966 to 1969. A concomitant of this rapid growth of the agriculture sector was the burgeoning of a small-scale engineering industry which supplies key durable-goods inputs, mainly diesel engines, pumps and strainers, but also various farm implements. According to the authors the industry has been a vehicle for marshalling indigenous "minor" savings/investible funds, for the development of entreprenural and managerial talent, and for the training of skilled and semi-skilled labor (Child & Kaneda, 1975).

Chancellor found that the purchase and use of tractors by farmers in Thailand and Malaysia have been increasing significantly in recent years, despite their high expense. Furthermore, a tractor-contractor system has been established giving virtually every farmer access to tractor service.

Almost every farmer hiring a tractor service combined the time saved and other resources to produce additional income. Although the enterprises varied, 65 percent (of 233) Thailand farmers and 75 percent (of 199) Malaysian farmers chose enterprises based on agricultural intensification of the type which would not displace labor. Real increases in agricultural production resulted from the use of tractor power for tillage. The increases did not take the presupposed form of better crop yields due to substituting machine for hand or animal methods of tillage. Rather, it freed the farmers' time to get involved in other productive activities in agriculture, i.e., many farmers diversified their operations. Only through the use of a tractor-contractor system, however, was it possible to reduce tractor charges to each farmer to a level where they could buy back their time from basic tillage activities at a cost low enough to permit them to re-invest their time in new productive enterprises (Chancellor, 1970).

The rapid expansion of tractor use was also the source of non-farm employment opportunities in Thailand and Malaysia. A large number of small manufacturing workshops produced spare tractor parts, tractor-attached implements, special wheel equipment for tractors, simple 2-wheel tractors, and power driven puddling machines. Also many tractor repair workshops sprang up. The establishment of these local businesses not only facilitated the purchase and use of tractor services, it also served as an important source of employment and vocational training. The increase in employment raised incomes and generated a much needed demand for a wide range of consumer goods.

Yudelman (1971) provides further empirical evidence, from developing countries around the world showing that mechanization of certain agricultural operations often leads to increased labor utilization as well as increased output.

D. Nature, Extent, and Consequences of Agricultural Mechanization in Latin America: Some Evidence

The purpose of this section is to synthesize available literature on agricultural mechanization in Latin America. Agricultural mechanization is considered primarily in terms of tractors and their use in the tillage process. The tractor is the "general factotum" of farm machinery, i.e., the purchase of one usually implies the purchase of auxiliary equipment as well (Abercrombie, 1972, p. 17).

Our discussion will focus on numbers and distribution of tractors; public policies that encourage tractor use; and, the effect of tractor use on crop production levels and employment opportunities.

Agricultural Mechanization. Abercrombie (1972, p. 10) notes that agricultural production is on the whole much more mechanized in Latin America than in other developing regions of the world. Although mechanization has been quite rapid (occurring primarily after W.W. II), it has penetrated only a small part of Latin America agriculture. It is mainly confined to some of the larger farms, and in most countries to the larger farms in certain geographical areas. Field visits, as part of this study, to Colombia, Costa Rica, Guatemala, and Honduras confirm most of the region's agricultural population still works without the help of either machinery or other technological improvements.

In Argentina, for example, 70 percent of the machinery is found in the pampas; in Brazil 95 percent is in the Central-South zone; in Colombia 70 percent is in eight departments (out of a total of 21); in Mexico 70 percent is in the North and Pacific zones and in Uruguay 80 percent is in the South and West (Abercrombie, 1972, p. 19).

The geographical concentration of tractors and farm machinery has a number of causes:

Table 1. Tractor Use in Selected Countries of Latin America

Country[1]	Year	Number of Tractors	Average horse power	Cultivated area[2] per tractor (ha)	Horsepower per cultivated ha[3]	Number of economically active persons in agriculture[3] per tractor	Per head income[4] (US$)	Percentage of population urbanized[1]
Cuba	1969	48,800	N/A	63	N/A	18	N/A	59
Uruguay	1968	28,000	40	90	0.45	6	628	76
Argentina	1968	180,000	48	155	0.31	8	851	75
Venezuela	1968	15,850	50	164	0.31	51	765	68
Chile	1968	25,000	41	180	0.23	28	585	67
Colombia	1968	23,000	53	220	0.24	109	336	51
Peru	1968	10,000	43	280	0.15	164	386	44
Costa Rica	1965	3,000	40	291	0.14	71	521	32
Nicaragua	1965	2,850	40	351	0.11	105	299	37
Brazil	1969	100,000	56	360	0.16	126	314	44
Mexico	1968	70,000	40	370	0.11	100	631	58
Guatemala	1965	3,800	40	418	0.10	224	337	29
El Salvador	1965	1,590	40	477	0.08	349	307	34
Paraguay	1969	1,700	50	590	0.08	203	257	32
Honduras	1965	1,400	40	640	0.06	300	229	24
Ecuador	1968	2,500	45	1,290	0.03	330	286	43
Bolivia	1968	1,600	50	1,930	0.03	583	184	33

Ranked in ascending order of cultivated area per tractor. [3]Arable land and land under permanent crops. [3]1965. [4]Gross domestic product per head at factor cost, 1968.

Sources: LAFTA, op. cit., p. 7; estimates for Central American countries from unpublished studies by the FAO Advisory Group for Central American Economic Integration; "Dos anos de desarrollo agrocuario cubano, 1968-1970," op. cit., p. 49; FAO: Production Yearbook 1969 (Rome, 1970), Vol. 23, pp. 21. United Nations: Statistical Bulletin for Latin America, Vol. VI, No. 2, Sep. 1969 (New York, Sales No. E 70.II.G.2), p. 23; United Nations, Economic Commission for Latin America: Economic Survey of Latin America 1968 (New York, Sales No. E 70.II.G.1), pp. 39-40.

Source: K. C. Abercrombie, "Agricultural Mechanization and Employment in Latin America," International Labor Organization Review, 106(1), July 1972, p. 18.

1. Because of the generally abundant land resources in Latin America, in most countries only limited zones have so far been intensively developed for agricultural production.

2. Many areas with steeply sloping land do not lend themselves easily to mechanization.

3. Certain crops, such as cereals, oilseeds, cotton, sugar-cane, potatoes and fodder crops like alfalfa are more susceptible to mechanization than others, and in many countries mechanization is heavily concentrated on a few of them.

4. The vast majority of farm holdings in Latin America are too small for the economical use of a tractor, or for their owners to be able to afford one. In a few countries, however, the possibility of renting farm equipment exists.

Tractor Distribution. Table 1 presents some basic information on tractor use for 17 Latin America countries for which fairly comparable recent estimates are available. As can be seen, the intensity of tractor use in relation to the cultivated area varies sharply among the different countries. Cuba which has engaged in very large imports of tractors in recent years emerges as the Latin American country whose agriculture is most intensively "tractorized." Evidently, labor shortages during various phases of sugar-cane production--land preparation, planting and harvesting--have encouraged this mechanization. In Argentina, Chile, Colombia, Uruguay and Venezuela there is one tractor for roughly every 100 to 200 hectares which is close to the level found in some developed countries with fairly extensive agriculture such as Australia and the USSR. At the other extreme, mechanization is almost negligible in Bolivia and Ecuador. Most of the remaining countries have one tractor for between 300 and 600 hectares. If the intensity of tractor use is measured against the agricultural labor force instead of the cultivated area, there is the same wide range of values among the countries, and their ranking remains more or less the same. The degree of tractor use appears to be quite closely related to the level of per capita income (Abercrombie, 1972, pp. 18-19).

Public Policies Encouraging Tractor Use. The policies of many Latin American countries have encouraged the adoption of agro-mechanical technology--tractor and other equipment. Abercrombie (1972, pp. 31-36) identifies a number of government policy related factors that enhance the profitability and convenience of (labor-saving) tractors and other equipment used by large farmers.

1. Factor prices have tended to be distorted so that the private entrepreneur has had to pay for capital at less than its opportunity cost to society and considerably more for labor than its opportunity cost.

2. Overvalued currency (exchange rates) encourages farmers in Latin America to purchase imported tractors even though their prices are sometimes twice as much as those paid by farmers in the developed countries where the tractors are produced.

3. Credit for the purchase of a tractor or other farm machinery is obtainable from government institutions for 70 to 100 percent of the

purchase price at much less than the commercial rate of interest. Also, in view of rapid inflation prevailing in many Latin American countries, the average rate of interest effectively charged by public institutions in recent years for agricultural machinery loans has frequently been negligible or even negative. Many farmers have had to pay back only from 50 to 80 percent of their loans.

4. Farm machinery is often exempt from import tariffs. At the same time domestic production enjoys considerable tax concessions.

5. Many Latin American countries offer free training at government schools for tractor drivers and mechanics, although this appears in general to be insignificant.

A number of factors affecting labor use have also encouraged the substitution of machinery for labor:

1. Minimum wage regulations and social security systems have greatly increased the cost of employing labor. Although both of these measures are much less effective in agriculture than in manufacturing, partly because of the isolation of many rural areas and because a portion of the agricultural wage is often paid in kind, they are gradually becoming more effective, especially on large farms that have been the major employers of hired labor.

2. Even where labor is still cheap, it is much easier on large farms to organize the work of a few skilled machinery operators and their equipment than that of large numbers of unskilled workers and associated numerous draft animals.

3. Social unrest that is spreading increasingly from the towns to the countryside in many Latin American countries is another incentive to mechanize.

Other factors encouraging mechanization in Latin America include:

1. Prestige associated with the possession of tractors and other mechanical equipment.

2. International loans have been fairly easy to obtain for mechanization projects and have financed many credit schemes for machinery purchases by farmers. Each of the Latin America Free Trade Association (LAFTA) countries has received one or more agricultural machinery loans from the World Bank, the United States Eximbank, or the United States Agency for International Development.

3. Tractor manufacturers, operating substantially below full capacity, are interested in expanding domestic markets and exporting under preferential regional arrangements.

Table 2: Effect of Agricultural Machinery on the Production Levels of Selected Crops, Colombia, 1971

Crop	Production Levels: Percent Increase: Between Traditional[1] and Mechanized[2] Farming Systems	Production Levels: Percent Increase: Increase Due to Use of Agricultural Machinery
Sesame	89.0	9.8
Cotton	118.0	10.1
Rice, Wet	101.0	14.8
Rice, Dry	41.0	15.6
Barley	31.0	14.9
Beans	51.0	9.4
Corn	162.0	10.0
Potatoes	61.0	15.0

Source: Juan Enrique Araya A., and Carlos Ossa E., La Mecanizacion en La Agricultura Colombiana, Bogota, 1976, p. 78.

[1]Traditional farming systems do not involve the use of modern inputs, i.e., motorized farm machinery and equipment, and improved seed varieties, chemical fertilizers, pesticides, etc.

[2]Mechanized farming systems involve the use of modern motorized farm machinery and equipment, plus the use of improved seed varieties, chemical fertilizers and pesticides.

Agricultural Mechanization and Crop Production Levels. As noted earlier, the principal effect of tractor (and other farm equipment) use on agricultural production levels is achieved, primarily, through the expansion of cultivated area and opportunities afforded for multiple cropping. The direct effect of tractors on yields per hectare is much smaller. It is generally agreed that, improvements such as the use of better seeds, fertilizers, pesticides, herbicides and water control have a far greater impact on yields, even though some mechanization can sometimes be an essential part of the overall technological package.

Very little data is available documenting the impact of tractor and other farm equipment use on agricultural production levels in Latin America. In a recent study in Colombia, however, an attempt has been made to measure the impact of agricultural mechanization on the production level of several crops (Araya & Ossa, 1976). A Colombian Ministery of Agriculture study group examined three different production technologies for nine principal crops. The first production technology or system, called the mechanized system, includes the use of agricultural machinery and high levels of other inputs--improved seeds, fertilizers, insecticides, and herbicides. The second production system, the modern system, includes the use of improved seeds, etc., but not agricultural machinery. The third production system, the traditional system, includes neither agricultural machinery nor the biochemical inputs--improved seed, chemical fertilizers, etc.

The reason for examining the three production systems was to isolate the separate effects of mechanization on production levels from the effects of the other modern inputs. Table 2 presents the results of the Colombian study. In interpreting the information provided in Table 2, the reader should keep in mind that the study made no mention of efforts to control for differences in farm size, soil quality, topography, or management. Nor did the study indicate the quantity or quality of agricultural machinery, improved seeds, fertilizers, pesticides, and herbicides used. Consequently, to the extent wide variations occur for these factors the degree to which the results can be generalized to other regions and countries is limited.

As figures in Table 2 indicate, the production increases associated with the mechanized, compared to the traditional system, range from 31 percent for barley to 162 percent for corn. However, production level increases attributed solely to the use of agricultural machinery are substantially less. Increases range from a low of 9.4 percent for beans to a high of 15.6 percent for dry rice. The study concludes that the use of agricultural machinery does contribute to increased crop production levels, but the use of bio-chemical inputs (improved seeds, chemical fertilizers) is the major factor responsible for production gains in many crops.

Unfortunately the study does not provide an economic analysis of the costs and returns of tractors and other farm equipment used to produce the crops. It may be that the returns earned from increased crop production levels for certain crops are not large enough to justify investment in the agricultural machinery.

Table 3. Labor Requirements Per Hectare, with and without Mechanization, for some main Field Crops in Selected Countries (man-days per hectare)

	Brazil[1]		Chile		Colombia			Guatemala		Paraguay	
Crop	Animal traction	Mechanized	Without mechanization	With mechanization	Traditional	Modern[2]	Modern mechanized	Human energy only	Human and mechanical energy	Without mechanization	Semi-mechanized
Barley	-	-	27[3]	8[3]	44	(62)	6	-	-	-	-
Beans	-	-	70[3]	50[3]	62	(82)	18	57	44	-	-
Cotton	98[4]	77[4,5]	-	-	82	(120)	66	107	94	57	26
Maize	69	43	60[3]	35[3]	49	(78)	30	56	44	48	8
Potatoes	-	-	75[3]	65[3]	125	(193)	156	162	153[6]	-	-
Rape seed	-	-	18	8	-	-	-	-	-	-	-
Rice, irrigated	-	-	48	33	71	(93)	36	103	54	85	26
Rice, rain fed	127	59	-	-	42	(54)	19	-	-	-	-
Sesame-seed	-	-	-	-	52	(68)	36	-	-	-	-
Soybeans	72	27[5]	-	-	-	-	-	-	-	-	-
Sugar-beet	-	-	100	90	-	-	-	-	-	-	-
Sunflower seed	-	-	45	30	-	-	-	-	-	-	-
Wheat	-	-	26[3]	10[3]	32	(63)	7	103	47	16	6[7]
Average[8]	-	-	52	37	62	(90)	41	98	73	-	-

[1]State of Sao Paulo. [2]Theoretical situation of improved agriculture without mechanization. [3]Irrigated. [4]Excluding harvesting. [5]With animal traction. [6]116 with human, animal and mechanical energy. [7]Fully mechanized. [8]Unweighted.

Sources: Unpublished data for 1971-72 from Divisao de Economia da Producao, Instituto de Economia Agricola, Sao Paulo; Banco del Estado de Chile, Servicio Agronomico; Ministerio de Agricultura: Consideraciones sobre el papel de la maquinaria en la agricultura colombiano (Bogota), op. cit., table 4; Ministerio de Agricultura: Sintesis de la situación del sector agropecuario de Guatemala (Guatemala, 1963) (quoted in Thorbecke and Stoutjesdijk, op. cit., p. 106); Ministerio de Agricultura y Ganadería: Cuentas culturales, principales, productos agrícolas, 1969-1970 (Asunción, 1971), pp. 3-6, 29-30, 53-54.

Source: K.C. Abercrombie, "Agricultural Mechanization and Employment in Latin America," International Labor Organization Review, 106(1), July 1972, p. 25.

Agricultural Mechanization and Employment. The possibility that adoption of agro-mechanical technology will lead to the loss of jobs in the agriculture sector concerns many people.

Open unemployment in Latin America at the end of the 1960s was estimated at 8.9 percent of the economically active population. When underemployment is included, the total unused labor amounted to 28.2 percent of the labor force (or 25 million persons) at the end of the decade (ILPES/CELADE, 1969, pp. 7-10). In the agricultural sector, underemployment appears generally to be much more serious than open unemployment. According to Brazil's 1970 population census, 25 percent of the agricultural labor force worked less than nine months in the year preceding the census and, in the six northeast states the figure was 38 percent (Brochl, 1970, p.24). It has been estimated that in Peru 57 percent of the available agricultural labor force work 200 or less days a year. (Thorbecke & Stoutjesdijk, 1971, p. 49).

Seasonal fluctuations in the demand for agricultural labor is a major feature of the agricultural employment situation in Latin America. Broadly speaking, over the year the larger farms require a substantial amount of casual and seasonal labor, whereas the smaller farms have a considerable labor surplus. While there is a sizeable movement of labor between these two subsectors, they far from balance one another. The seasonal peak demand on the larger farms rarely coincides with the peak supply on the smaller farms, unless widely separated geographical areas are considered (Abercrombie, 1972, p. 15).

One study estimated that in Chile the total demand for agricultural labor in July is 63 percent of the demand in March (Ministerio de Agricultura, 1968, p. V-112). In Peru the demand in September is estimated at only 27 percent of that in June, and in one province in February it is estimated to be only 0.4 percent of the May level (Convenio para Estudios Económicos Básicos, 1970).

Seasonal labor shortages and other factors (discussed earlier) have encouraged many Latin American farmers to mechanize, often resulting in the displacement of farm labor. Estimates of the employment effects of the mechanization of agriculture in selected Latin American countries are presented in Table 3. Labor requirementes per hectare with and without mechanization, for selected field crops are shown for Brazil, Chile, Colombia, Guatemala and Paraguay.

As can be seen, labor requirements differ substantially from crop to crop, both with and without mechanization. Labor requirements for barley and wheat have been sharply reduced by mechanization. On the other hand, potatoes and sugar-beets, with the highest labor requirements of all crops, are the least affected by mechanization.

Table 4 illustrates the job loss effect (measured in percentage terms) of mechanization for selected crops and countries.

Table 4. Labor Displaced Due to Mechanization, Selected Crops and Countries

	Labor Displaced Man-Days Per Hectare (Percent)				
	Country				
Crop	Brazil	Chile	Colombia	Guatemala	Paraguay
Beans	-	28	78	23	-
Maize	38	42	39	21	83
Potatoes	-	13	25	5	-
Wheat	-	62	72	54	59

Source: Derived from Table 3.

The (percentage) figures presented in Table 4 suggest that the mechanized production of certain crops leads to a sizeable displacement of labor. Nevertheless, the data are incomplete for determining the full impact mechanization has had on employment; information on the final fate of the displaced labor is necessary before any conclusions can be drawn. It may be that labor released from land preparation, for example, was employed in other phases of the production process--planting, cultivating, harvesting, etc. The likelihood of such an occurrence increases if mechanization leads to multiple cropping. There is also a wide variance in labor displaced between countries for the same crop. This may be due to the use of larger tractors in some countries, as compared to others, and/or because certain countries have chosen to mechanize more phases of the production of certain crops than others have. Field visits indicated that agricultural mechanization, in general, is greater in Colombia than in the other three countries visited--Costa Rica, Guatemala and Honduras.

In Colombia it was found that there has been a wide variation in labor displacement (job loss) rates among crops following the adoption of agricultural machinery, with or without the joint use of improved seed varieties, chemical fertilizers and pesticides (Table 5). An explanation for the wide differences in labor displacement rates among crops requires reference to the labor requirements of the various phases of production. In the production of some crops it is easier to substitute machinery for labor. In wheat and barley production, for example, labor is employed in land preparation, seeding, and harvest; phases of production that are easily mechanized. The Colombian study indicates that the rate of substitution of machinery for labor (between the mechanized system

Table 5. Labor Saved and Labor--Agricultural Machinery Rate of Substitution for Selected Crops, Colombia, 1970

Crop	Mechanized System[1] versus Traditional System[2]		Mechanized System versus Modern System[3]	
	Labor Saved, Percent	Rate of Substitution Man-Days/Machine Hours	Labor Saved, Percent	Rate of Substitution Man-Days/Machine Hours
Sesame	48.0	4.18	46.0	2.89
Cotton	51.0	3.65	45.0	3.27
Rice, Wet	55.0	5.16	60.0	4.61
Rice, Dry	63.0	3.91	66.0	3.47
Barley	98.8	5.70	82.0	4.95
Wheat	89.0	5.30	88.0	5.10
Beans	73.0	4.91	78.0	4.28
Corn	42.0	5.18	61.5	4.08
Potatoes	4.0	1.22	20.0	2.44

Source: Juan Enrique Araya A., and Carlos Ossa E., La Mecanizacion en la Agricultura Colombiana, Bogota, 1976, p. 84.

[1]Mechanized farm systems involve the use of modern, motorized farm machinery and equipment, plus the use of improved seed varieties, chemical fertilizers and pesticides.

[2]Traditional farm systems do not involve the use of modern inputs, i.e., motorized farm machinery and equipment, and improved seed varieties, chemical fertilizers and insecticides.

[3]Modern farm systems involve the use of improved seed varieties, chemical fertilizers and insecticides, but do not involve the use of motorized farm machinery and equipment.

and the modern system) is 3.4 man-days per machine-hour in land preparation and seeding, 4.5 man-days per machine-hour in cultivation, and 5.3 man-days per machine-hour in harvesting.

In other words, for the nine Colombian crops studied, on the average, agricultural mechanization displaces the largest number of laborers in the harvest phase of crop production. The results are of special interest for the design of mechanization policies as they affect the objectives of production and employment. According to the Colombian study land preparation and seeding are the phases in which mechanization can achieve its greatest increase in crop production levels; mechanization of these phases also results in fewer jobs lost, relative to mechanization of harvesting (Araya & Ossa, 1976, p. 84-85). A field visit to the Cauca Valley in Colombia found widespread use of tractors in land preparation, seeding and cultivation of a number of crops on large farms.

Data from the Colombian study also reveal the effect bio-chemical inputs have on the demand for labor at the farm level. Table 6 compares the labor requirements per hectare of the three production technologies--traditional, modern and mechanized. Averaging labor requirements per hectare for the nine crops it is found that shifting from a traditional system to a mechanized system without modern inputs such as improved seed, fertilizer, etc., results in a 50 percent reduction in labor requirements. However, when a shift is made from a traditional system to a mechanized system also using improved seeds, fertilizers, and pesticides, there is only a 34 percent drop in the demand for labor. The increased demand for labor due to higher yields from the use of seeds, fertilizers, etc., partially offsets the decline in labor demanded due to mechanization.

Whether the rate and magnitude of labor displacement in the production of selected Colombian crops due to mechanization is similar to other Latin American countries is an empirical question to be answered by future research.

A recent study of agricultural development efforts in several Central American countries also documents the labor displacing (job loss) effects of mechanization (GAFICA/SIECA, 1974). In Honduras, for example, it has been estimated that mechanizing one hectare of corn production will result in an overall decline of 53.5 man-days per hectare (Table 7). The relative displacement of labor is even greater when all phases of corn production are considered. Mechanization of soil preparation and seeding displaces 97 percent of the labor required by non-mechanized production; 61 percent and 57 percent of labor required for the non-mechanized cultivation and harvesting phases, respectively, are replaced with mechanization. The displacement of labor is substantially less with the substitution of animal traction or semi-mechanized traction for manual labor in the production of one hectare of corn.

Table 6. Labor Requirements per Hectare, with and without Mechanization, for Selected Crops, Colombia, 1970 (Man-Days per Hectare)

Crops	Farm Systems			
	Traditional[1]	Modern,[2] but Not Mechanized	Mechanized,[3] with Modern Inputs	Mechanized without Modern Inputs
Barley	44.0	62.0	6.0	0.5
Beans	62.0	82.0	18.0	16.0
Cotton	82.0	120.0	66.0	40.0
Corn	49.0	78.0	30.0	28.0
Potatoes	125.0	193.0	156.0	120.0
Rice, Wet	71.0	93.0	36.0	32.0
Rice, Dry	42.0	54.0	19.0	15.0
Sesame	52.0	68.0	36.0	27.0
Wheat	32.0	63.0	7.0	0.5
Average	62.0	90.0	41.0	31.0

Source: Juan Enrique Araya A., and Carlos Ossa E., La Mecanizacion en La Agricultura Colombiana, Bogota, 1976, p. 85.

[1]Traditional farm systems do not involve the use of modern inputs, i.e., motorized farm machinery and equipment, and improved seed varieties, chemical fertilizers and pesticides.

[2]Modern farm systems involve the use of improved seed varieties, chemical fertilizers and insecticides, but do not involve the use of motorized farm machinery and equipment.

[3]Mechanized farm systems involve the use of motorized farm machinery and equipment, plus the use of improved seed varieties, chemical fertilizers and insecticides.

Table 7. Honduras: Labor Use in Production of One Hectare of Corn on Farms[a] with Different Levels of Mechanization, 1966.

Mechanization	Man-Days Per Hectare			
	Preparation of Soil & Seeding	Cultivation	Harvest	Total
Mechanized	0.7	9.2	9.6	19.5
Partially Mechanized	11.5	15.2	22.8	49.5
Animal Traction	17.6	17.3	22.5	57.4
Hand Labor	27.0	23.5	22.5	73.0

[a] Farm size ranges from 1 to 7 hectares.

Source: GAFICA, based on "Costos de Producción de Maíz, Frijol, etc.," Secretaria de Recursos Naturales, Servicio Cooperativo de Desarrollo Rural, Tegucigalpa, C.A., 1968.

Information (Table 8) is available on the distribution of tractors and labor requirements by farm size in Costa Rica.

In the past decade several Central and South American countries have begun to extensively mechanize their agricultural export sectors. This has sharply reduced employment opportunities for casual and seasonal labor, particularly in the production of cotton, sugar-cane and bananas. Imports of cotton harvesters in Nicaragua, for example, have increased from 13 in 1963 to 200 in 1970. The cotton harvesters have reduced the demand for labor by 80 workers per hectare per year (GAFICA/SIECA, 1974, pp. 51-53). In Bolivia where mechanization of cotton production is occurring at a rapid pace, it has been argued that labor shortages would disappear if wage rates were allowed to be determined in the market place. Though wages would be higher than those fixed by the cotton growers' association, the extra labor costs would be offset by increasing revenue from the additional area harvested--up to 20 percent of the crop was lost in the early and mid 1970s because of labor shortages (Zuvekas, 1977, pp. 45-46).

Further, Zuvekas (1977, p. 46) argues that the present push of the cotton growers' association to mechanize may be very short-sighted. A shift to mechanical harvesters would not only displace tens of thousands of seasonal laborers, but might be more expensive in the long run if erratic world market conditions force some farmers to keep their machinery idle when prices are unattractive. Moreover, machanical harvesting lowers the quality of cotton, thereby, reducing its competitiveness on the world market. On the other hand, disregarding the social costs associated with the displaced labor, mechanization of cotton may be profitable if it permits double-cropping with soybeans and wheat.

Table 8. Costa Rica: Number of Tractors and Labor Requirements on Farms of Three Different Sizes, 1970

Farm of:	Less Than 4 Hectares	4 to 35 Hectares	More Than 35 Hectares
Total Area Cultivated (Ha)[a]	44,900	278,300	726,500
Total Number of Tractors Under Private Ownership[b]	70	720	4,180
Total Labor Requirements (Man-Years)[c]	10,160	58,660	111,700
Tractors per Hectare	0.0016	0.0026	0.0057
Labor Requirements per Hectare (Man-Years)	0.2260	0.2106	0.1537

[a]Includes fallow land and land in cultivation, but does not include pasture.

[b]1970 figures were estimated by adding the number of tractors imported between 1963-1970 to 1963 Census figures.

[c]Man-years corresponds to 280 man-days per year, labor requirements are for both cultivated and uncultivated land.

Source: GAFICA/SIECA, Perspectivas Para el Desarrollo y la Integración de la Agricultura en Centroamérica, Guatemala, 1974.

Selective Agricultural Mechanization. Colombian officials have acknowledged the importance of selective mechanization in the agriculture sector. They indicate that emphasis should be given to those types of mechanization that most effectively complement other yield-increasing improvements--soil preparation, planting, harvesting, and storage. This would help achieve the dual development objectives of increased food production and the generation of employment opportunities (Ministerio de Agricultura, 1971, pp. 31-35).

Summary. The following conclusions can be drawn from the information presented in this section:

(1) Because many Latin American countries have, consciously or unconsciously, encouraged agricultural mechanization through various policies that distort factor prices, overvalue currency, subsidize credit, etc., the net benefits of mechanization of the agricultural sector are often in doubt. Thirsk(1972), for example, conducted a study to determine whether the Colombian government's policy of subsidizing credit (at half the market rate) had increased or decreased GNP and employment, and whether the benefits of mechanization had accrued to the owners of land, labor, or capital. It was concluded that mechanization had lowered GNP, favored the capital-owning segment of society and resulted in lower agricultural employment (Thirsk, 1972, pp. 52-54; Gemmill & Eicher, 1973, pp. 37-38).

(2) Selective mechanization of phases of agricultural production cycle offers potential for increasing food production and employment through intensive use (multiple cropping) of given land holdings. Many of the larger farms in Latin America, however, are notórious for their underutilization of land and the owner's lack of interest in intensifying production. Consequently, the opportunities for generating additional employment are not realized. For example, substantial amounts of land at lower elevations in Guatemala is being farmed extensively. There is little evidence of multiple cropping and substantial land areas appear to remain fallow for two or three years between plantings.

(3) Selective agricultural mechanization, coupled with the use of new seed varieties, chemical fertilizers and irrigation, offers the greatest potential for increasing both food production and employment.

E. Costs and Returns of Tractor Ownership and Use in Selected Latin American Countries

Financial and Economic Profitability - A Distinction. A distinction must be made between the profitability of tractor use to an individual (private or financial profitability) and the profitability of tractor use to the country as a whole (economic profitability) (Gittinger, 1972).

For the purposes of this section, attention is focused on the private or financial profitability of tractor ownership and use. This does not mean that the consequences--economic profitability--of tractor use on a regional or country basis should be ignored. However, the focus here will be on the individual farmer.

A number of factors determine the profitability of tractor ownership and use, a few of which are considered in this section. Tractors and auxiliary equipment are "lumpy" inputs. They represent a fixed asset with a potential flow of services over a period of time. To be utilized efficiently tractors, for example, must achieve a minimum level of use. This level can be achieved either through extensive use, i.e., expanding the total area cultivated, or through intensive use, i.e., increasing the intensity of use on a given cultivable area. Generally the larger the tractor (H.P.) the greater the level of minimum use required to achieve efficient use. The profitability of a large tractor in the small farm sector requires spreading the "services" over a large number of small farm units. This can be accomplished through either the provision of private tractor-hire services or a publicly sponsored tractor service center.

Optimum Tractor Power. For the small farmer desiring to own a tractor rather than purchase services from private or public sources, the question of the optimum tractor size becomes important. The farmer requires sufficient traction power to accomplish his farming operations on a timely basis, but should avoid excess power that cannot be used profitably.

William J. Chancellor (1968) has developed a methodology for determining the horsepower needs of a small farmer. He proposes that the optimum tractor size can be estimated from the following formula:

$$H \text{ (optimum horsepower)} = \frac{[LW(C + D)]^{1/2}}{(AK)^{1/2}}$$

where

A = the ratio of annual fixed charges to initial tractor cost,

K = initial cost of tractor per rated horsepower,

C = operation costs which are proportional to time of operation,

L = land area worked per year,

W = rated horsepower hours required per year for each unit of land,

D = the average penalty in cost per hectare/working hour for the delay between the time a cultural operation is started on a given farm and the time it is completed (e.g., getting the crop planted or harvested).

Presently, the lack of data for Latin American farm operations of differing sizes prevents using Chancellor's formula to determine the optimum tractor size. Farm level studies in the future are needed to provide such information.

Chancellor (1968, pp. 509-511) shows that the optimum power rating (H.P.) of the tractor to be selected by a farmer increases with:

a. increased land area handled (with added emphasis when timeliness is important),
b. increased intensity of mechanical cultivation operations for each hectare,
c. increased operator wage,
d. increased economic importance in avoiding delays in scheduling,
e. decreased cost per rated horsepower, and
f. decreased rate of fixed costs associated with tractor ownership.

Finally, in comparing highly mechanized areas with those in which tractor mechanization is just beginning, Chancellor (1968, p. 510) finds that the optimum tractor size selected by farmers in the latter area is generally smaller. The reasons for this are:

a. farms are smaller,
b. fewer operations are suited to tractor power,
c. operator wages are lower, and
d. fixed costs are higher (due to higher interest rates and more rapid deterioration of tractor materials).

It is generally accepted that tractors of 40 to 60 H.P. require an arable area of more than 40 to 50 hectares for their economical use (Abercrombie, 1972, p. 19). In view of the present size distribution of land in Latin America, the vast majority of holdings are far too small for the economical use of a large tractor.

Nevertheless, the availability of traction power is important for increasing the productivity of the small farmer. But the question of what types of traction power are appropriate for the small farmer remains to be answered. A recent study in Venezuela sought to answer this question (Espinal & Cedeno, 1970). In the study three modes of traction power--four-wheel garden tractors, two-wheel walking tractors, and a pair of burros--were compared on the following performance criteria:

1. Field Capacity--the amount of work accomplished per unit of time, i.e., hectares per hour,

2. Field Efficiency--the degree to which actual effective capacity achieves theoretical effective capacity, and

3. Variable Costs--including fuel, oil, repairs and maintenance, and labor.

Although the three modes of traction power were tested at different locations, efforts were made to control for differences in topography and soil type. Also the three modes engaged in the same agricultural operations--plowing, harrowing, cultivating, listering, and ridging.

The field test results are presented in Table 9. While the four-wheel garden tractor costs more to operate, it was superior in field efficiency and effective capacity. The variable costs for operating the four-wheel garden tractor were 1.6 times higher than the two-wheel walking tractor, and 6 times greater than the burros (Espinal & Cedeno, 1970, p. 24).

Table 9. Performance Comparison for the Three Types of Traction Power

Activity	Performance Criteria	Four-Wheeled Garden Tractor	Two-Wheeled Walking Tractor	Two Burros
Plowing	Field Efficiency (%)	72.60	52.00	--
	Efficiency Capacity (Ha per 10 hrs)	.88	.25	--
Harrowing	Field Efficiency (%)	67.40	50.00	--
	Efficiency Capacity (Ha per 10 hrs)	2.94	.74	--
Cultivating	Field Efficiency (%)	76.20	44.50	61.40
	Efficiency Capacity (Ha per 10 hrs)	4.11	.54	.60
Listering	Field Efficiency (%)	78.90	83.00	68.60
	Efficiency Capacity (Ha per 10 hrs)	4.37	1.98	1.07
Ridging	Field Efficiency	---	69.60	78.00
	Efficiency Capacity (Ha per 10 hrs)	---	1.83	1.22

Source: Alfonso Perez Espenal and Oscar Cedeno, Estudio Comparativo de Tres Formas Diferentes de Mecanizacion en Labores Agricolas.

Other Factors Affecting the Profitability of Tractor Use. In addition to power rating, a number of other factors influence the profitability of tractor use by a small farmers, i.e., tractor design, initial cost, access to credit, availability of repair service and spare parts, farmer's experience in tractor use, and access to markets for surplus production to mention only a few.

Tractor and farm equipment implement design are particularly important for many small farm plots. In some Latin American countries the majority of small farms can be found in the highlands, on the side of steep hills, in ravines and gullies. The land is often covered with rocks and tree stumps which prevent tractors of standard design from operating effectively.

For many small farmers the lack of credit and high initial cost of a tractor (and other farm equipment) prevent their purchase. For those small farmers that secure credit the inability of many of them to repay their loans results in debt and further problems. In most cases, the farmer defaults on his loan because of factors that prevent him from either realizing or marketing the increase in production expected to result from the use of a tractor.[1]

Machinery dealers contacted on field visits to Colombia, Costa Rica, Guatemala and Honduras repeatedly stated that the small farmer's lack of experience with tractors, his inability to make simple repairs, and his difficulty in getting spare parts, and similar problems result in his tractor sitting idle during important phases of crop production--land preparation, cultivation and harvest. Consequently, the farmer frequently loses the opportunity for multiple cropping and increased crop production. The failure to increase crop production reduces the farmer's income, thereby reducing his ability to meet his loan payment schedule.

A small farmer may expand his total crop production two- or three-fold only to find that inadequate on-farm storage and lack of transportation prevent him from successfully marketing his crops. Again, the loss in potential revenue can create loan repayment problems for the farmer. On-farm storage is important in two respects: (1) it reduces the farmer's crop loss thereby increasing the amount available to market, and (2) it allow the farmer to hold his crop until market prices are favorable.

Tractor Costs and Returns. Tractor ownership and operating costs are closely associated with tractor size, i.e., horsepower. Balis (1977, Appendix J), in a study on appropriate mechanization in Nicaragua, presents data on ownership and operating costs of different size tractors. A portion of his data is presented in Table 10. Although Balis does not analyze the data provided in Table 10, it can be observed that:

1. Ownership and operating costs per hour fall with a decline in horsepower, and

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[1]For a more complete discussion of small farmer credit problems, see Small Farmer Credit in South America, AID Spring Review of Small Farmer Credit, Volume III, February 1973, No. SR 103, Country Papers.

Table 10. Comparison of Operating and Financial Aspects of Selected Tractors[1] in Nicaragua

Make	Model	Horse Power (H.P.)	Purchase Price (C$)	Operating Time Per Year/Hrs	Ownership & Operating Cost/ Hr/ (C$)	Farm Operations	Time to Complete Farm Operations Days/MZ	
							Animal	Tractor
John Deere	2130	79	95,625 (11,475)*	2,000	53.44 (6.41)	Land preparations and seeding	8 hrs.	2 hrs.
Massey-Ferguson	265	69	78,500 (9,420)	2,000	42.00 (5.04)	"	8 hrs.	1 hr.
David Brown	990	58	69,000 (8,280)	2,000	29.10 (3.49)	"	8 hrs.	.5 hr.
John Deere	1020	49	59,680 (7,162)	2,000	39.20 (4.70)	"	8 hrs.	1 hr.
Kubota	L-285	30	39,850 (4,782)	2,000	20.77 (12.49)	"	8 hrs.	3 hrs.
Kubota	L-225 D.T.	24	38.650 (4,638)	2,000	18.58 (2.23)	"	8 hrs.	3 hrs.
Satoh	Beaver	15	22,450 (2,694)	2,000	14.00 (1.68)	"	8 hrs.	4 hrs.
Kubota	B-600R	12.5	31,500 (3,780)	2,000	13.76 (1.65)	"	8 hrs.	---

Source: "Informacion Necessaria Para Evaluar El Projecto De Alquiler De Manquinera o Equipo," (Balis. J., 1977, Appendix J).

*Number in ( ) are US$.

[1]Where trade names are used no discrimination is intended and no endorsement by the Inter-American Bank is implied.

2. Tractors require about one-fourth to one-half the time animals require to complete the same tasks of soil preparation and seeding.

A recent study in Guatemala on increasing the productivity of small farmers provides additional costs and return data on the use of tractors (BANDESA, 1962). The study concludes (obvious to many) that a tractor for use by small farmers should be well constructed, compact, and versatile and it should be easy to handle, and low priced so that the small farmers can earn a satisfactory return on their investments (BANDESA, 1972, p. 6).

For reasons not given in the study, the authors focus on a 24 H.P. tractor and auxiliary equipment. Given a 24 H.P. tractor, they conclude that the minimum size farm necessary to justify mechanization is 23 manzanas or 16 hectares (BANDESA, 1972, p. 12). The profitability of the tractor and auxiliary equipment is illustrated with cost and revenue figures for three crops--corn, sesame, and wheat (Table 11). The study suggest a high rate of return for tractor use in the production of the three crops. The study is puzzling, howeve in that it proclaims a concern for small farmers, yet its focus is on a farm size holding of 16 hectares, while the average farm size in Guatemala is 8 hectares, and the farm size of 90 percent of the farmers is well below the average (Fletcher, et al., 1970).

Additional information on the level of tractor use in Latin America was acquired through direct interviews with government officials, farm equipment and implement dealers, and small farmers in several countries.

Discussions with several farm equipment and implement dealers in Guatemala indicate that a variety of tractors and auxiliary equipment are being marketed. Although the tractors are small (below 35 H.P.) relative to tractors being sold in most Latin American countries (see Table 1), few are being purchased by small farmers. Lack of credit and aversion to risk are the primary reasons given for the small farmers' low level of tractor purchases.

A firm in Guatemala sells a twin cyclinder 30-35 H.P. tractor called the Nibbi. The smallest Nibbi unit sells for $4,900 and the largest for $6,900 and sales are approximately one per month. Nibbi sales have been mostly to large sugar cane producers for disking and harrowing between rows. The Nibbi has allowed the producers to plant their sugar cane rows closer together, thereby increasing total production. Another consequence, according to the distribution of the use of the Nibbi has been the displacement of labor on sugar cane plantations. Estimates on the number of laborers displaced per hectare, or per Nibbi, were not available.

A second popular tractor being purchased by large sugar cane producers in Guatemala is the 12.5 H.P. Kubota. Sales have increased sharply from 60 units in 1970 to 200 units in 1977 and projected sales for 1978 are for 250-300 units. The Kubota with implements for plowing and disking sells for $4,250.

Even though the Kubota is inexpensive relative to most tractors in Latin America, the majority of farmers in Guatemala cannot afford it.

Table 11. Estimated Costs and Revenues for Corn, Sesame, and Wheat Per Manzana

Guatemala, 1972

(Q = quetzal)

	CORN		SESAME		WHEAT	
Tractor and Auxiliary Equipment[1] Costs		Q 51.72		Q 45.47		Q 35.43
Land Preparation	Q 17.12		Q 17.12		Q 17.12	
Seeding	Q 4.02		Q 4.02		Q 4.02	
Cultivation	Q 18.08		Q 13.08		Q 8.04	
Harvest	Q 12.50		Q 11.25		Q 6.25	
Bio-Chemical Costs		Q 28.00		Q 31.00		Q 40.00
Seeds	Q 3.00		Q 1.00		Q 10.00	
Fertilizer	Q 20.00		Q 20.00		Q 20.00	
Insecticides	Q 5.00		Q 10.00		Q 10.00	
Cost per Manzana		Q 79.72		Q 76.47		Q 75.43
Yield per Manzana (in quintales)	55 qq		15 qq		25 qq	
Gross Revenue per Manzana		Q 112.50 (50 qq x Q 2.25)		Q 225.00 (25 qq x Q 9.00)		Q 150.00 (25 qq x Q 6.00)
Net Revenue per Manzana		Q 32.78		Q 148.53		Q 74.57
Net Revenue for 24 Manzanas (16 hectares)		Q 786.72		Q3564.72		Q1789.68
Net Revenue for 2 Harvests (per Year)		Q1573.44		N/A		N/A
Rate of Return		41.25%		110.28%		98.68%

[1]Tractor 24 H.P., two-bottom plow, harrow, two-furrow seeder, and two-furrow cultivator.

Source: Considerciones Generales Para Dotar De Maquinaria Agricola al Mediano Y Pequeno Agricultor, BANDESA Guatemala, 1972.

It has been estimated that eight manzanas of intensive crops are needed to justify the purchase of a Kubota. Over 70 percent of the farms in Guatemala, however, are less than 6 manzanas and are not cropped intensively (Fletcher, et al., 1970). Although credit to purchase the Kubota and other tractors is available --40 percent down, 14 percent interest and up to two years to pay (AGRITROP, 1977)-- the average income of the small Guatemalan farmer ($50-$150 annually) is clearly inadequate. The down payment required is 11 to 34 times greater than the average farmer's annual income.

According to an official of SIECA, several studies in Guatemala show that farmers who own tractors are underutilizing them by as much as 50 percent of their potential operating time. The reasons given for this are frequent breakdowns, lack of qualified drivers, and the unwillingness of the large farmers to cultivate their land on an intensive basis.

Field visits in Costa Rica indicate that there are seven firms selling small tractors in San Jose. Two or three of the firms plan to discontinue their sale of small tractors because the profit per unit sold is small and the marketing costs are high.

The head of the production department of UNACOOP, a cooperative confederation with about 35,000 members and 70 percent small farmers, strongly supported a Swiss-made, small tractor, called "Rapid." It sells for about $3,100 and all the auxiliary equipment adds another $1,500. Sales have been slow (17 units in 24 months). Again, high capital costs and unwillingness of the small farmer to risk such an investment were the reasons given for the poor sales. Credit terms for purchasing the "Rapid" appear to be more favorable than those for the Kubota in Guatemala. The farmer would have to pay 10 percent down, 11 percent interest and is given up to four years to repay the loan. Even though the average income for a small farmer in Costa Rica is about twice ($100-$250) that of his counterpart in Guatemala, he would still have to make a down payment that is two to four times his annual income. In addition, few small farmers are willing to mortgage their land and other possessions to secure a loan. Even if the small farmer could, somehow, obtain the down payment there is very little hope he could increase his annual income enough to pay off the loan in four years!

An UNACOOP study indicated that at least eight hectares of potatoes are required to justify the purchase of a "Rapid." Yet 50 percent of all farms in Costa Rica are less than five hectares (BIO, 1977). The study showed that the gains from substituting tractor power for hand power in the cultivation of potatoes are doubtful. On the basis of cost-effectiveness, tractors have only a slight advantage ($20 per hectare) over hand labor in the cultivation of one hectare of potatoes (Table 12).

Justification of tractor use on such a slim cost advantage seems questionable, particularly when capital risks are taken into consideration. However, the farmer may improve the return to his investment by using the tractor in the production of other crops or by hiring out tractor services.

Table 12. Hand Labor vs. "Rapid" Tractor Costs in the Cultivation of One Hectare of Potatoes, Costa Rica.

Power Source	Hours	Labor Costs (hr)	Equipment Costs (hectare)	Total Costs (colones)
Hand Labor	304	4 colones/hr	--	1216
"Rapid"	166	4 colones/hr	$532	1196

Source: Mr. Roland Abinden R., Chief, Production Department, UNACOOP, San Jose, Costa Rica, November 29, 1977.

There are other reasons to consider besides ownership and operating costs for the small farm family when purchasing a "Rapid" or similar tractor. In the case of potatoe production presented here, the farmer can employ himself and his family labor over 300 hours using hand labor, but slightly less than half of this time when using the "Rapid." When on-farm and off-farm employment is limited, the farmer may choose to use hand labor.

Summary. The limited nature of available data and information prevents drawing firm conclusions about the economics of tractor ownership and use in Latin America. However, based on the material reviewed in this section and field visits, a few observations can be made.

1. Although small tractors (12-35 H.P.) are available on a limited basis in many Latin America countries, few small farmers own or make use of their services. There are a number of reasons for this, including the size and topography of small farm holdings; financial barriers to tractor (and other farm equipment) ownership, high down payments, high interest rates, short repayment periods; and the strong reluctance of small farmers to take capital risks.

2. Large farmers in Latin America are purchasing tractors, of all sizes, at an increasing rate. Government policies that distort factor prices make the substitution of tractors for hand labor profitable. Imperfections in rural labor markets contribute to seasonal labor shortages and high priced labor, further encouraging the substitution of agricultural machinery for farm labor. In addition, the availability of "cheap" agricultural machinery often encourages large land owners oriented to the export market to dissolve rental agreements with small farmers so that large tracts of land can be put together to accommodate the use of 80 and 90 H.P. tractors and combines. It would appear that if current agricultural mechanization policies and trends in many Latin American countries continue the outcome will be greater concentration of land

use in the hands of a few, greater unemployment in the rural areas, and probably little, if any, increases in food production levels.

3. If small farmers are to take advantage of available modern agricultural technologies, government policies sensitive to their needs and conditions are needed. For example, a credit program that underwrites the costs (e.g., initial costs and finance charges) of small farmer ownership of farm equipment should be considered. Likewise, consideration should be given to financial incentives and organizational assistance necessary to encourage small farmers to form farm equipment cooperatives. Also, public and/or private tractor-hire schemes, should be evaluated -they have worked successfully in other parts of the world.

III. Description of Agro-Mechanical Technologies With Emphasis on Small Farms in Selected Latin American Countries

The purpose of this section is to provide technical information on small farm agro-mechanical technology. A constraint to increased production in many instances is the time required for certain field operations, in particular tillage and harvesting. In such cases, adequate mechanization to overcome time constraints can lead to multiple cropping, increased food production and employment opportunities. Storage and irrigation are also phases of the agricultural production cycle that affect food supply levels and employment opportunities.

Section III contains six sub-sections. Sub-section A focuses on tillage with technical comments on power sources for tillage implements. (These power sources are also applicable to other operations.) Sub-sections B-F discuss irrigation, harvesting, storage and considerations in promoting agro-mechanical technologies.

A. Primary and Secondary Tillage: Power Sources and Implements

The basic purpose of tillage is to properly prepare soil to receive either seeds, young plants, tubers, or other forms of plant life for subsequent optimum production of food or fiber. Primary tillage can be defined as the initial loosening or breaking up of the soil for subsequent refinement by secondary tillage. Stout (1966) elaborated on this simplistic definition, mainly for rice production, but the concepts apply to other crops. Primary tillage may also aerate the soil when excessively wet, initiate the process of cutting and distributing organic matter and killing grass and weeds. Secondary tillage is the process of further soil refinement which usually creates an environment favorable for the seed and plant to grow, but it may also act to kill grass and weeds and help to incorporate organic matter.

By the nature of the operation, tillage imposes one of the main power requirements on farming. According to Hunt (1973), over half of the power expended in a highly mechanized system is used for tillage. Hand and animal powered systems also expend about one-half of the total energy expended on tillage. Thus tillage is usually an important process to mechanize early.

The following discussion centers on alternative engine power sources for tillage implements.

Engine Power. Engine power for farm implements comes in a variety of forms. The single axle tiller is the simplest form and usually has horsepower ranging from less than 2.5 to 25 H.P. These tillers normally have an air-cooled engine that burns gasoline. In many countries the cost and availability of gasoline is a problem. Tillers that burn diesel fuel are available but have a higher initial cost and weight. Discussions with machinery manufacturers and farmers in Colombia, Costa Rica, Guatemala and Honduras, however, suggest these air-cooled engines have a reputation for needing frequent repairs. For the uneducated small farmer, this problem of engine maintenance is a major barrier.

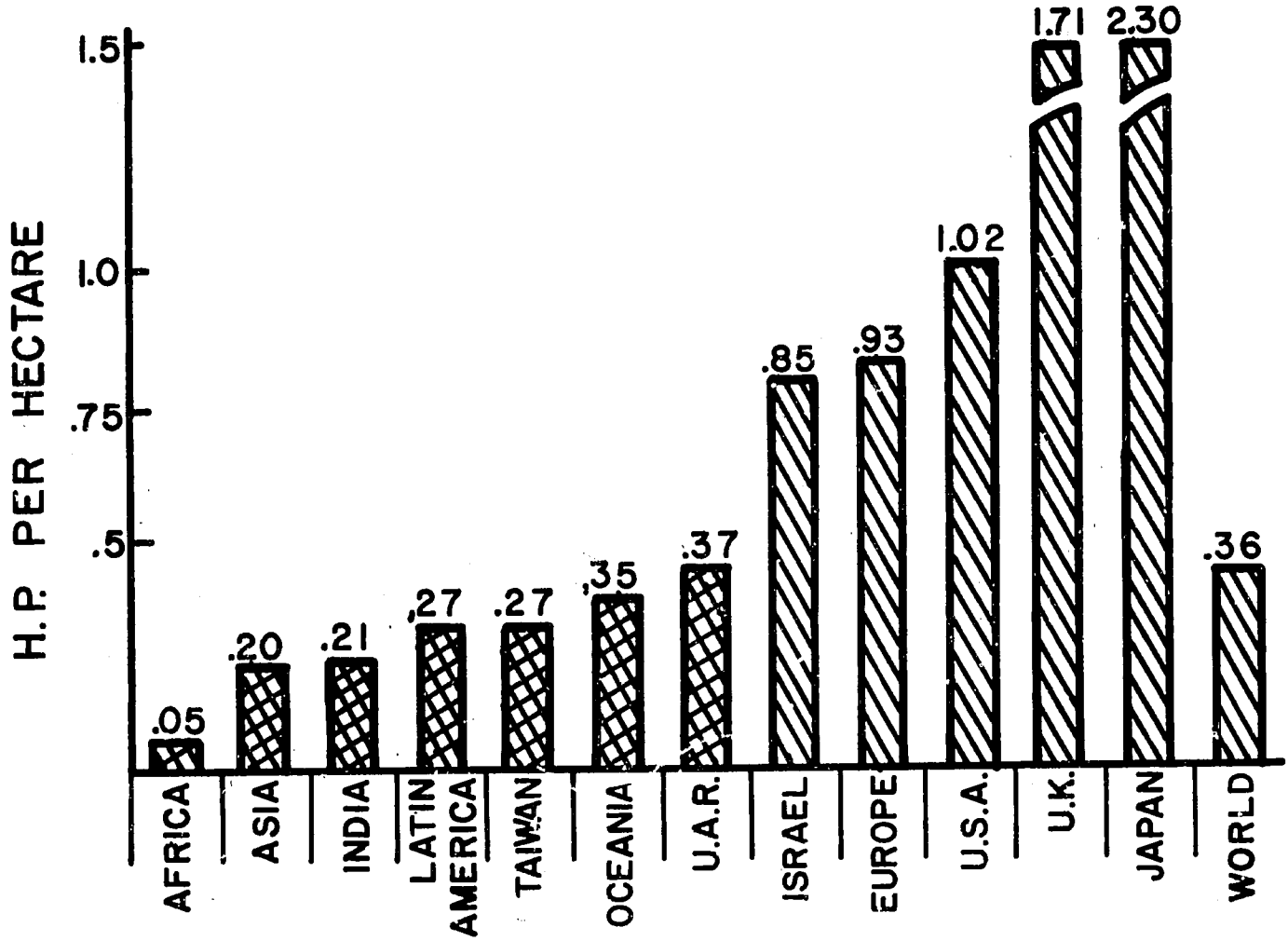


Figure 1. Power available per hectare for the major areas of the world.

In Latin America the more popular form of engine power is the four-wheel tractor, with power ranging from 8 to over 200 H.P. Just as animal power enables a man to work more land area, so engine power enables man to work more acreage than animals. The actual amount of power required for a given area will be discussed later.

Figure 1 (Hall, 1973) provides a comparative picture of the power available per hectare of arable land and land under permanent crops for 1964-65. Figure 1 indicates that the developing countries have significantly less engine power available; a more realistic picture, however, would be a similar graph which would include an estimate of the power available from the agricultural labor force and from draft animals. It is recognized that a given amount of energy will be required to accomplish a particular task. Thus to say that any area does not have enough power per hectare on the basis of engine power alone is misleading.

From field visits it appears that most small farmers in Latin America who make use of engine power, especially for tillage, do so either through arrangements with large-scale farmers or through cooperatives. One small farmer in the Cauca Valley of Colombia stated that a nearby large farmer tills his ground when needed. Another farmer who had two hectares had purchased a used tractor for working his own land as well as doing contract work for neighbors. A cooperative representative in Guatemala stated that they are taking a critical look at their mechanization program. They had purchased five tractors (each about 50 H.P.) with tillage equipment and were losing money.

A machinery dealer in Guatemala City who is successfully marketing a four-wheel drive 12.5 H.P. diesel tractor made in Japan provided valuable information. He is an innovative dealer who has designed and built several pieces of equipment to go with this tractor. However, the tractor is being purchased mainly by large farmers in the coastal regions of Guatemala for sugar cane cultivation. (This point is discussed in Section II, pp. 49-50.) The dealer indicated the high initial cost of the tractor severely limits its use among small farmers. In addition, the representative of a cooperative which had purchased several of these small tractors stated that the small wheels did not provide sufficient flotation for the tractor to work in the loose volcanic type soils of the mountain regions of Guatemala. The tractor is shown in Figure 2.

In the mountainous terrain of the countries visited it was obvious that the slopes are too steep for the use of any currently available engine powered machines. Many of the steep hillsides have been cleared, farmed for short period of time, then abandoned when the fertile topsoil is washed down the hillside. Two types of agriculture are possible in these regions: (1) growing permanent perennial crops, in which case engine powered mechanization is not required, or (2) proper terracing for annual crops so that the soil can be conserved, in which case the use of appropriate agricultural machinery has its place.

The comment was frequently made, particularly in Guatemala, that a way is needed to test various agro-mechanical technologies for their technical

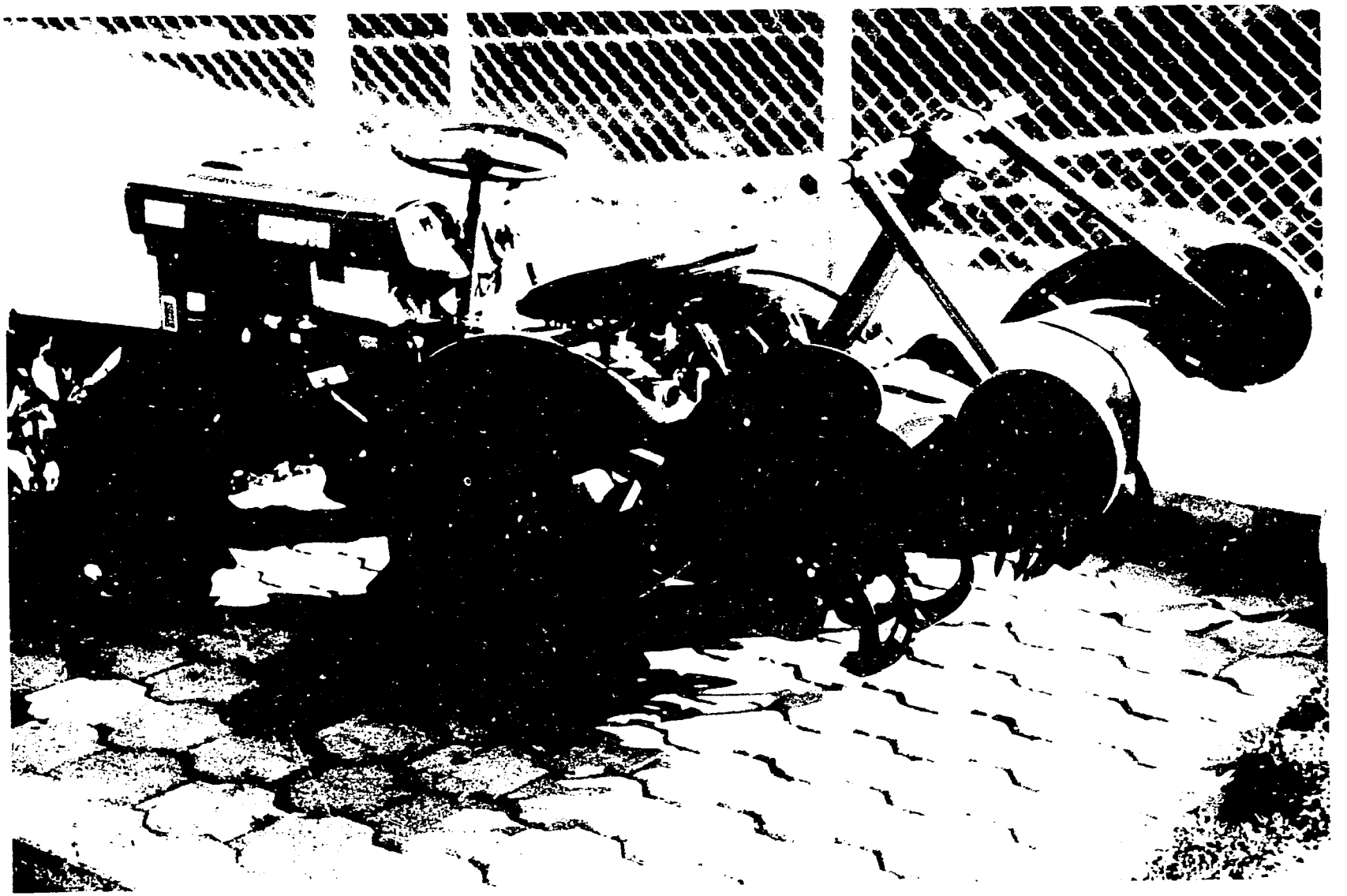


Figure 2. 12.5 hp diesel powered tractor with rototiller in Guatemala

and economic appropriateness for small farmers. For example, the small inexpensive garden-type tiller in wide use in the U.S. may be appropriate for many small farmers in Latin America. Nevertheless, field tests under various conditions are necessary before widespread adoption of the garden tiller can occur. To date, however, few field stations exist in Latin America to test agro-mechanical technologies.

The next subsection deals briefly with the topic of the selection of appropriate sized engines.

Selection of Engine Power. Chancellor (1968) provides an economic framework to guide in choosing the appropriate size tractor (horsepower) necessary to meet the power requirements of small farmers. He develops a set of equations of minimize total annual tractor costs (i.e., fixed costs, operating costs and time-related costs). (See Section II, pp. 40-42.)

Hunt (1973) presents a more complete approach to the problem of power selection. Again based on the concept of minimizing annual cost, he presents equations which can be solved to determine not only the appropriate tractor horsepower for a specific farm, but includes the selection of appropirate size implements to go with the farm. A computer program is available from Hunt (1973) to solve his system of equations since manual solution for large farm system is complex and tedious. The program finds the optimum systems for a range of tractor power levels, allowing the machinery manager to insert personal judgement. Hunt's work was designed for and has been applied to the highly mechanized systems of the United States, but might be adjusted for use in developing countries.

The work done by Chancellor (1968) and Hunt (1973) is applicable to Latin America. However, use of their methods will require the collection of data under prevailing conditions in Latin America.

In an examination of the agricultural practices of the Cauca Valley of Colombia, it was found that the large farmers use relatively large tractors (50 H.P. and above) for land preparation and transportation. Land preparation, however, is the only time when farmers need all available (horsepower) power; this is particularly true during the rainy season when timeliness of planting is important for achieving maximum yields. Transportation, harvesting and other activities normally require less horsepower and can be accomplished with smaller tractors. Nevertheless, the low price and availability of fuel (30¢ per gallon for diesel, 40¢ per gallon for gasoline), plus other factors discussed earlier, encourage farmers to use tractors that are larger than necessary.

Engine Powered Tillage Implements. The rotary tiller is a popular low-power (usually less than 15 H.P.) method of providing primary tillage on small acreages in Asia. The two basic types of rotary tillers are: (1) the rotary blade assembly which suports the engine and frame, tills and provides forward motion, and (2) wheels are used to provide forward motion and support the engine and frame while the tiller is attached to the front or rear of the frame. The rotary tiller pulverizes the soil in one pass and usually leaves a more finely prepared seedbed than does a plow. Usually the only secondary tillage

required is minor raking with a hand rake. The wheel type tiller is much easier to operate than the simple single axle type, but it often costs twice as much. Operating costs will be similar if the horsepower is equivalent.

For small farmer mechanization the rotary tiller should be one initial considered. Many different types and sizes of rotary tillers are manufactured in the U.S. and Europe for gardening purposes. They are manufactured and used extensively in Japan by full-time small farmers. The International Rice Research institute (IRRI) initiated a unique research program to develop machinery for small rice farmers with less than 10 hectares. McMennemy (1976) reported that IRRI has developed a 5-7 H.P. tiller that makes maximum use of standard machine components that are readily available in most developing countries. It was found during field visits that IRRI has a subcontractor located in Cali, Colombia (Kaeser, 1977). It was stated that one small manufacturer has made three of the IRRI tillers in Palmira, Colombia but it appears that improved marketing of the tiller is needed.

The moldboard plow and the disc plow are the two major tractor drawn implements. (The moldboard plow is discussed in greater detail in the animal powered implement section.) With sufficient horsepower, more than one plow can be pulled to speed up the task. There are often two major problems in using small four-wheeled riding tractors --insufficient clearance and inadequate traction for plowing.

As explained by Stone and Gulvin (1967),the disc plow is recommended for plowing in adverse conditions such as wet, sticky soils and in soils with rocks or stumps because it will ride over such obstacles, rather than hanging on them. Automatic tripping moldboard plows are available for such conditions, but at an additional cost. The disc plow is made up of a group of sharpened discs that use angle and weight for penetration. The disc plow does not leave a flat plow sole (i.e., a flat hardened surface under the disturbed soil) as does a moldboard plow. Maintenance costs on disc plows are usually less than for moldboard plows. The draft of a disc plow will be approximately the same as for a moldboard plow under similar conditions. The main advantages of a moldboard plow are that it provides a more complete coverage and incorporation of organic matter and provides better soil tilth. In general, the initial cost of either tool will be similar per unit width. In discussions with emplement dealers and farmers, it was found that the disc plow is used almost exclusively in the countries visited. The main reason given was that the disc plow is preferred for its ability to perform well on rough terrain. Farmers in Colombia indicated a preference for disc plows made in the U.S., though there are several manufacturers in Colombia and the imported disc plows are more costly. The reason given was that the bearings and disc blades of locally made equipment have a significantly shorter life, and it was felt that the increased initial cost of imported equipment was offset by maintenance cost of indigenous equipment.

Following primary tillage by moldboard plow or disc plow, secondary tillage is necessary. Either type pf primary tillage will leave large chunks of soil and organic matter. The refinement of this seedbed is usually accomplished with a disc harrow. The disc harrow is constructed much like the disc plow, except with smaller diameter discs. A leading set of discs is turned in one direction and the following set in the other direction so that soil is thrown in both directions in one pass.

A spiked-tooth harrow is often used to follow the disc harrow for final smoothing and refinement of the soil particles. It consists of a wood or metal frame (usually metal for engine powered applications) with metal spikes protruding downward which are drawn through the soil. The steel framework is preferred for longer harrow life and also so that the angle of the teeth can be adjusted.

Animal Power. A number of different animals are used in Latin America to power farm implements. This includes the horse, mule, donkey, and ox. The advantage of animal power over human power is that most animals can exert substantially more power on a continuous basis. They are relatively inexpensive and they supply services other than power such as milk and meat. They are "fueled" by a renewable energy source.

Hopfen (1969) provided the information shown in Table 13. He pointed out that weight and size have an influence on power output of suitable harnesses. Hopfen (1969) has an excellent description of harnesses. Stout (1966) discusses the power output of selected harnesses and yokes.

Table 13. Normal Draft Power of Various Animals

Animal	Average weight	Approximate draught	Average speed of work	Power developed	
	Kg.	Kg.	M/s	Kgm/s	HP
Light horses	400-700	60-80	1.0	75	1.00
Bullocks	500-900	60-80	0.6-0.85	56	0.75
Buffaloes	400-900	50-80	0.8-0.9	55	0.75
Cows	400-600	50-60	0.7	35	0.45
Mules	350-500	50-60	0.9-1.0	52	0.70
Donkeys	200-300	30-40	0.7	25	0.35

Source: Hopfen, J. H., 1969. Farm Implements for Arid and Tropical Regions. FAO Ag. Dev. Paper No. 91, FAO, Rome.

Table 14 provides information (Hopfen, 1969) on the average draft requirements of selected farm implements. It can be seen that in most operations more than one animal is required to conduct the operation on a continuous basis.

Discussions with engineers at the Instituto Colombiano Agropecuario (ICA) experiment station in Bogotá provided valuable insight into the use of draft animals. For several years ICA has been developing new animal-drawn equipment.

Animal-Powered Tillage Implements. The plow with its numerous variations is the major animal-powered primary tillage implement. Two main types of plows are found in Latin America--the symmetric breaking type ("ard" is its ancient name) and the asymmetric type (commonly known as "moldboard" plow) (Hopfen, 1969). Either plow consists of a beam, body, handle and share. The share and point are usually steel to resist wear, but the remainder may be wood or steel.

The ard (also called a "double moldboard" or "lister" in U.S.) throws soil in both directions, does not invert the soil and leaves vegetation on the surface to die. It is relatively easy to handle because of symmetry. It is a shallow tillage implement for use in semiarid areas. As explained by Stone and Gulvin (1967) the lister will prepare about twice as much soil in a given time as a moldboard plow. The lister will form ridges and furrows and the land under the ridge is not tilled.

The moldboard plow lifts a band of soil of a given width and depth, while inverting and breaking the band. It will leave the field relatively level with the organic matter burrowed. Because of the complete action of tilling all soil to a given depth, the moldboard plow is generally the preferred animal-powered primary tillage implement.

An unusual type of animal-drawn moldboard plow was found at the facilities of a small machinery manufacturer in Palmira, Colombia. According to the manufacturer, a similar plow was brought from the U.S. years ago, and he had copied the design. The moldboard and share are attached to a hinge pin so that the position of the moldboard and share are reversible (see Figure 3). This type of reversible plow is necessary when it is not feasible to plow in a circular pattern, as is the case of the small mountain farmer.

ICA has developed in recent years a small disc plow to be pulled by a team of oxen. Several manufacturers are constructing and selling this plow to small farmers (0.5 to 1 hectare) in the Andean mountains around Bogota and in the sourhtern region of Colombia. They supply engineering plans to interested manufacturers and conduct a program of demonstrating the use of the disc plow. These farmers have traditionally used wooden plows for soil preparation. The disc plow costs about US$ 340. Since it has a working width of 1.2 m as compared with 20 cm for a wooden plow, the disc plow can prepare the same land area in about one-third the time as a wooden plow. The disc plow also has a longer life. Engineers at ICA stated that the small farmers in the mountains are showing some acceptance of the oxen disc plow.

The most common type of animal-powered secondary tillage equipment is the spiked-tooth harrow. This implement was previously described under the sub-section on engine-powered tillage equipment.

Figure 3. Reversible ox-drawn plow for hillside plowing in Colombia

Table 14. Draft Requirements of some Farm Implements for Operations on Medium Loam Soils

Operations	Draft Requirements
	Kg
Ploughing fallow land with single moldboard	
11.4 cm wide, 12.7 cm deep	89
14.0 cm wide, 12.7 cm deep	94
16.5 cm wide, 15.2 cm deep	121
25.0 cm wide, 18.0 cm deep	170
Ploughing fallow land with double moldboard	
30 cm wide, 5.5 cm deep	116
Harrowing ploughed soil	
18-tine peg tooth harrow, 6.3 cm deep	46
5 spring tines, 11.4 cm deep	118
heavy harrowing 165-320 cm wide	80-100
light harrowing 320 cm wide	90
Levelling ploughed soil with a 180-cm-long board ridden by a person of 53 kg weight	90
Rolling	96
Cultivating, 3-tine cultivator, 9 cm deep	53
Seed drilling, 175-200 cm wide, 11-13 openers	90
Wheeled transport of loads up to 1 metric ton on average farm roads	90-120

Source: Hopfen, H.J. 1969. Farm Implements for Arid and Tropical Regions. FAO Ag. Dev. Paper No. 91, FAO, Rome.

Human Power. Man is one source of power that always exists in agricultural production, whether to power or control an implement. However, man is limited to a power output of about 0.1 horsepower (hereafter abbreviated H.P.) in heavy labor over extended periods (Bolz & Tuve, 1970). A well-trained man has a physiological limit of 0.5 H.P. for steady work, can exert 0.6 H.P. for a few minutes and can exert 2 H.P. for a few seconds.

A major limiting factor in continuous output and long-term health is posture. Many hand tools such as the short-handled hoe are not designed properly to maximize output while minimizing input. Research on the design of a more efficient hoe may provide rich dividends.

Another limiting factor is the amount of force or torque required of the human. In general, the maximum force that a young adult male can exert for short terms as a steady push or pull is 45.4 kg. (100 lbs.) (Bolz & Tuve, 1970).

As pointed out by Hopfen (1969), a hand tool should be designed to minimize fatigue. This can be accomplished by designing it so that the required working motions follow natural movement and in such a way that as many muscles as possible are used in an alternating sequence.

It is generally found that one man and his family can farm from one to seven hectares using simple hand tools such as the machete, hoe and shovel. The area depends upon terrain, water supply, crops grown and their sequence of production. Two small farms visited in the vicinity of Cali, Colombia, of one hectare each were single family farms. One farm was in the flat plain of the Cauca Valley where the farmer grew fruits and vegetables. The other farm was in the Andean mountains west of Cali and was on extremely steep terrain which could only be farmed with hand tools and on which fruits, vegetables, coffee and corn were grown. Another small farm in the Cauca Valley had two hectares on which a father and his three sons were growing corn and tomatoes in rotation. All work except primary tillage was done by hand and/or with a hoe.

Among the highland Indian farmers of Guatemala it was found that one man and his family were farming about two hectares, mainly with a hoe. The unterraced terrain is often extremely steep for row crops (slopes as much as 45° and 50°) and thus can only be farmed for short periods of time (see Figure 4). The principal crop is corn. Wheat and beans also produced, and in some cases vegetables such as radishes and broccoli are grown to sell in urban markets.

Small farmers use one of two basic types of machetes: the straight or the hooked machete, with the straight machete being the most common. The straight machete is usually about 76 cm. long; the hooked machete is about 36 cm. long. It is used not only for clearing, but also for cultivation, chopping wood and woodworking. The machete is essentially a blade with attached handle.

Fig.4- Many small farmers in Central America must cultivate mountaneous terrain.

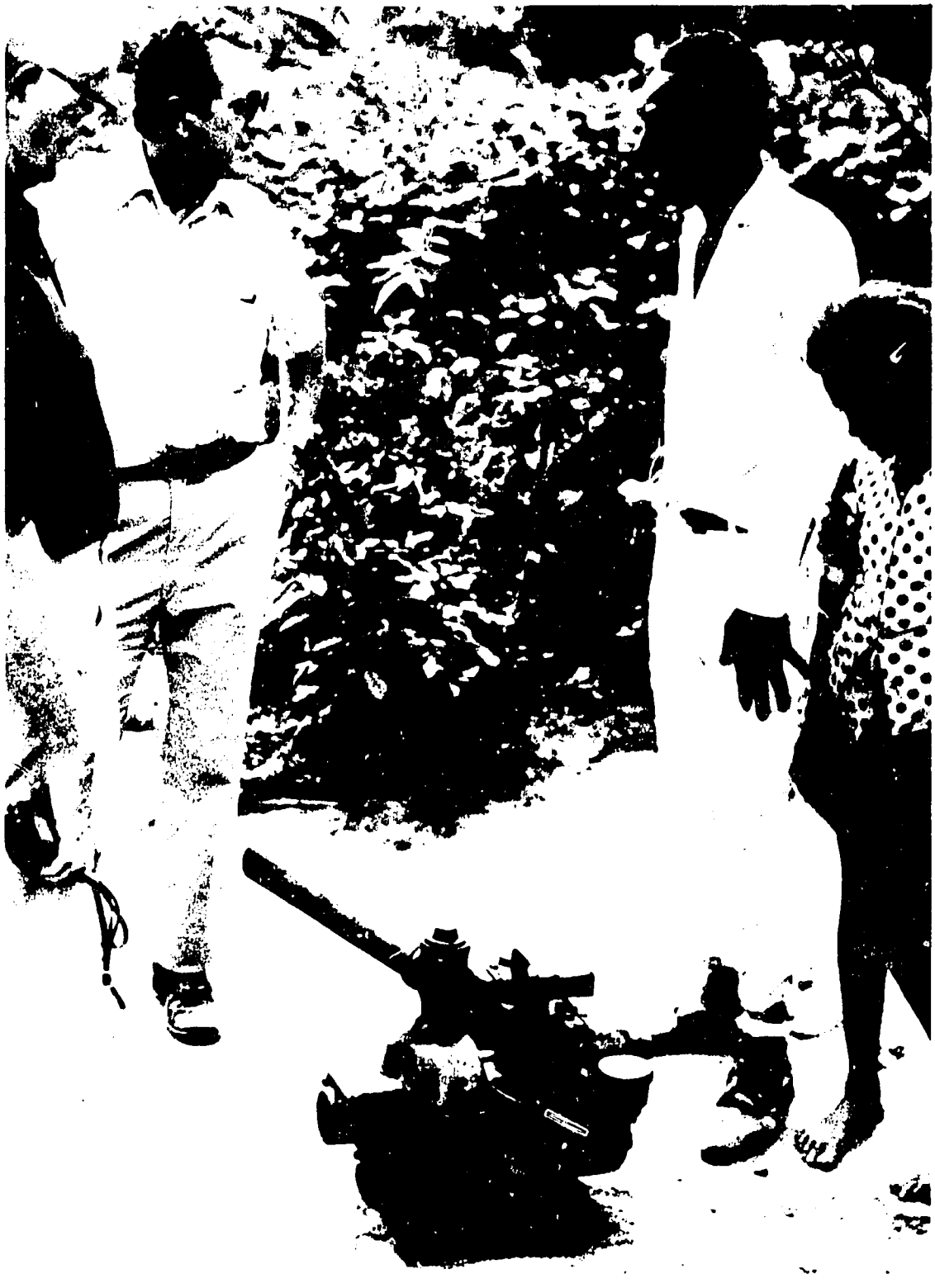


Figure 5. Farmer in Colombia with air-cooled gasoline engine powered irrigation pump.

Many different types of hoes were observed in the countries visited. Hopfen (1969) comments on the design of hand implements such as the hoe. Hand tools are made with a controlling handle (hand and/or foot) and the working part. The working part of the hoe is steel to resit wear and stress. Proper tempering is important to tool life. The controlling handles of a length, diameter, weight and flexibility requiring a minimum of power from the operator and easy to grasp and apply power must be securely attached to the working part. The handle is usually made of wood which is preferably obtained from a sapling grown on poor soil, with the root-end attached to the working part. Any necessary curves in the handle are obtained by steam bending, not by cutting across the wood grain. A paint or varnish finish should not be applied to the handle.

In summary, it was found that small farmers (in the countries visited) tilled by tractor, with animal drawn equipment, or the hoe, with the latter being the predominant method. The key to the introduction of mechanized tillage equipment is its economical and technical feasibility. It is obvious that most small farmers cannot afford a four-wheel tractor and in many cases, especially mountainous terrain, neither is it technically appropriate. The expanded use of draft animals is constrained by at least two factors--the time required to increase the animal population and the area required to produce food for the animals. The rotary tiller might supply the engine powered tillage requirements of many small farmers in Latin America. However, before any firm conclusions can be reached, field tests under various conditions are required.

The remaining technical sub-sections deal with the topics of irrigation, harvesting, and storage. Though technical comments on planting and weeding are not included in this report, it should be noted that the appropriate mechanization of these two activities can be important, but especially planting. For many annual crops, total production and timeliness of maturation are significantly influenced by planting.

B. Irrigation

Crop yields can usually be significantly increased with the application of the right amount of water at the right time through irrigation--timeliness of application is a key factor. Irrigation requires certain implements such as pumps that perform tasks that would be difficult if not impossible to accomplish manually, therefore, irrigation should be given serious consideration for early mechanization.

The timing and amount of rainfall are the two factors which control the type and level of irrigation to be applied to an area. As noted by Wilkinson and Kidder (1973) agricultural areas can be divided into three fairly distinct types in defining irrigation needs:

1. Arid and semi-arid areas where irrigation is essential to a viable agriculture;

2. Areas that experience water shortages during the critical growth periods of crop production. Annual rainfall may appear to be sufficient, but the timing of the rainfall is not sufficient; and

3. Humid areas that require occasional irrigation during some seasons and some years.

Wilkinson and Kidder (1973) provide information on the area of irrigated land in South American countries in 1963. More recent statistics were not found. It is estimated that about 80 percent of the irrigated land of Latin America is in Mexico, Chile, Peru and Argentina. They estimated that if capital were available and government support assured, more than 12 million hectares of irrigated land could be developed. Among others Bolivia, Colombia, and Ecuador have areas that potentially could benefit from irrigation.

Over the centuries the traditional methods of irrigation have been flood and furrow irrigation. Both methods require land forming. Flood irrigation is accomplished by constructing a dike around various areas of a field in which the change in ground elevation in the area is small. Then water is pumped into the area, creating a pond of water. Depending on the soil type and the existence of an impervious soil layer, the field may be flooded for long or short periods. Furrow irrigation is achieved by leveling a field so that there is a slight fall in elevation from one end to the other. The crop is planted on top of ridges and water is allowed to run down the furrow adjacent to each ridge for a given period of time until the soil is properly saturated. Very steep terrain has been adapted to flood irrigation in Southeast Asia, especially Japan. But, flood or furrow irrigation are best suited for level terrain. Low initial investments and operating costs are the main advantages of flood and furrow irrigation.

Another form of irrigation is known as sub-irrigation (Wilkinson & Kidder, 1973). This type is appropriate to special soil conditions where there is an impermeable soil layer of two meters depth, with permeable soil above. Ditches about one meter deep are dug at intervals 30 to 100 meters across the field. The ditch is kept full of water so that water moves through the permeable layer.

Sprinkler irrigation is a new method of irrigation that is popular in many parts of the world. This method requires a powered pump to produce water flow with a good pressure, pipes to convey the water, and some type of sprinkler to distribute the water. One distribution system that requires considerable labor to move the system from field to field is one in which sprinklers are attached to short sections of pipe that have quick couplers on each end. Mechanical systems that have been devised to overcome the labor requirements include:

1. pipes on wheels so they can be rolled by hand or towed by tractor,
2. center pivot systems, and
3. volume gun with drag hose.

All of these systems have high initial and operating costs and consume significant amounts of energy. They do not require land forming and can operate on both level and fairly steep terrain. They are suitable for essentially any soil type. Thus the real advantage of sprinkler irrigation is its versatility but because of high costs it is adaptable mainly to high value crops. Another

disadvantage of sprinkler irrigation is that evaporative losses can be high.

The newest method of irrigation adaptable to perennial crops such as coffee and fruit is trickle or drip irrigation. With this technique, low-cost plastic pipes are installed in a field, either temporarily on the surface or permanently underground. At the location of each tree, one or more emitters are attached to the pipe. These emitters allow small quantities of water to slowly emerge and wet the soil in the vicinity of the emitter. Evaporative losses are low and large areas can be irrigated simultaneously with a limited water supply. The initial investments and the operating costs are lower than sprinkler irrigation. Drip irrigation requires a clean water supply or the emitters will clog.

For a more thorough explanation of these irrigation methods, including engineering designs and costs, see Pillsbury (1968), Booher (1974), and Molenaar (1956).

Very little irrigation was observed among small farmers in field visits to Colombia and Central America. One farmer interviewed using furrow irrigation raised fruits and vegetables on one hectare in the Cauca Valley of Colombia and had a well and a small-pump driven by an air-cooled gasoline engine (see Figure 5). Other types of irrigation observed included the channeling of small streams to crops in the fields and the use of containers (buckets) to carry water to individual plants.

Irrigation can benefit the small farmer in a number of ways. First, it permits the cultivation of a larger unit of land and can lead to multiple cropping. In both cases, irrigation will likely result in increases in total production and the demand for labor (and other inputs). Efforts to promote irrigation in the small farm sector should include consideration of the following points:

1. the use of furrow or flood irrigation appears to be feasible and economical during the dry season if the terrain allows this type, and

2. the use of drip irrigation for permanent crops such as coffee, bananas or plaintains could be feasible and economical during the dry season.

The major investment for either system would be an engine powered pump. In many cases electricity is not available, therefore, a gasoline or diesel engine would be required. In mountainous regions, irrigation can be accomplished by the use of inexpensive plastic pipes and gravity flow and would be especially applicable to perennial crops.

C. Harvesting

It appears from visits to Colombia, Costa Rica, Guatemala and Honduras that mechanical harvesting occurs mainly for small grain crops and cotton and

then only by the large farmer. The grain, fruit, and vegetable crops grown by the small farmer are all harvested by hand. This discussion is limited to small grains.

The large farmers use grain combines made in the U.S. and Europe. Since this report emphasizes the small farmer, a description of mobile grain combines is presented here. For the small farmer it does not appear that the use of mobile combines in small fields is feasible. For example, a 1976 CIAT report (CIAT, 1976) indicated that:

> Contract harvesting of rice by combines is available in Colombia for approximately U.S. $16 per metric ton when there is sufficient harvest area to utilize the combine for several days. Areas of less than 10 hectares or harvests of less than 60 tons are probably not sufficiently attractive for the contractor.

In Guatemala agricultural specialists stated that the use of modern mobile combines on small farms appears to be uneconomical.

It was stated in field visits that harvesting of small grain is usually done by hand in which the stalk is cut with a knife, sickle, or scythe; the stalks are then tied in bundles and left standing in the field to dry. Following drying, the grain is removed by hand or by stationary machine threshing. Threshing of small grain was not observed because it was not the harvest season in the areas visited. However, several sources stated that hand threshing is accomplished by several means of beating the dried plants against a hard surface. Because of the number of plants and number of grains per plant, it is obvious that this process requires a long period of time. If climatic conditions become adverse or insect populations increase before all of the grain is properly threshed and stored, losses may be extremely high. In addition, if the farmer has to spend excessive time harvesting, multiple cropping is unlikely. For these reasons, appropriate threshing machines for the small farmer are important.

In Colombia a hand thresher has been developed at the CIAT (1976) experiment station. The device consists of a simple oil drum with deflecting walls attached on three sides. A man beats the plants against a funnel-shaped surface on top of the drum, causing the grain to fall through the funnel to be collected in a container.

The CIAT (1976) station reported that they had obtained a small engine powered thresher developed by IRRI (see McMennamy & Policarpio, 1977, for a complete description). Photographs and specifications are given in Figures 6a and 6b. A small machine shop in Palmira, Colombia has manufactured and sold one of these threshers for US$ 2.121 and plans to build and market three more this year.

CIAT (1976) reported comparative tests of their hand thresher and the IRRI axial flow thresher. They found that the IRRI thresher had a higher output but questioned its economic feasibility, particularly for smaller farmers.

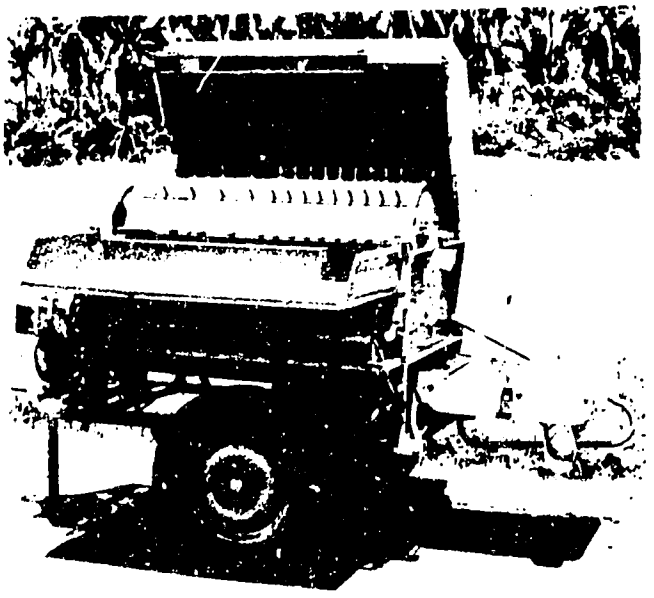
IRRI axial flow thresher

Threshes paddy, sorghum, soybeans, and other small grain crops.

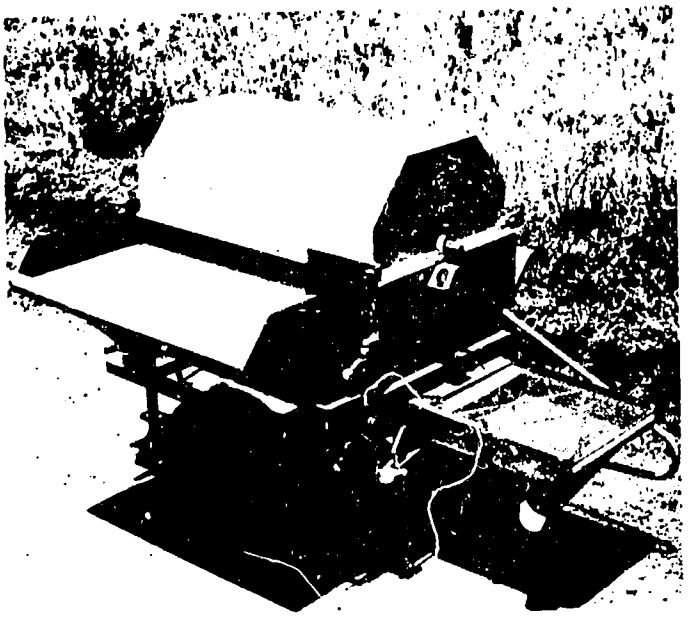
Features

HIGH OUTPUT	One ton per hour when threshing paddy
LOW HORSEPOWER REQUIREMENT	7 hp engine
LOW LABOR REQUIREMENT	Three to four men to feed, thresh, and bag grain
EASE OF OPERATION	Simplicity of design reduces operation and maintenance problems
THRESHING AND WINNOWING COMBINED	Throw-in threshing combined with air and screen cleaning mechanisms
HIGHLY MOBILE	Can be moved behind small hand tractor, jeep or truck

Figure 6a.



Threshing cylinder and upper concave exposed.



Throw-in design results in high output.

Machine specifications

POWER	7 hp engine
WEIGHT (with engine)	430 kg
LENGTH	258.45 cm
WIDTH	130.18 cm
HEIGHT	
With wheel	158.12 cm
Without wheel	111.76 cm
CAPACITY	up to 1 t/h (rough rice)
SEPARATION RECOVERY	98% (weight basis)
CYLINDER	Spiketooth, 39.8 cm O.D. x 122.0 cm length
CONSTRUCTION	All steel
COMPONENT SPEEDS	
Cylinder	500–530 rpm
Fan	1,030 rpm
Oscillating screen (frequency)	334–354 cycles/min
Oscillating screen (stroke)	0.925 cm
ADJUSTMENTS	Angle of air deflector and engine speed
LABOR REQUIREMENTS	3–4 men

For further particulars write: International Rice Research Institute, P. O. Box 933, Manila, Philippines
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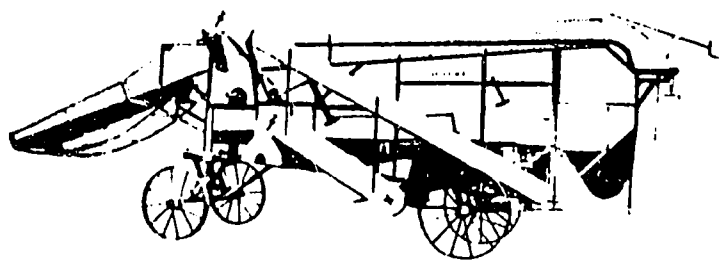

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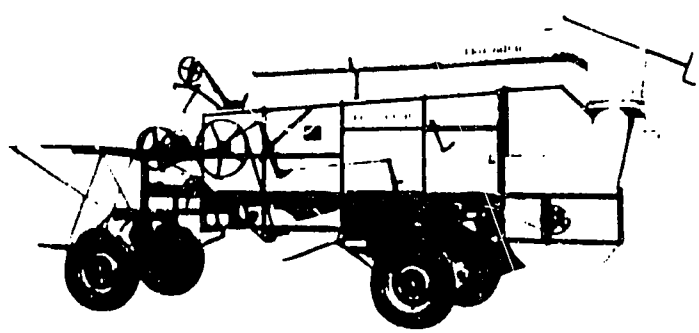
FRIEDRICH THRESHING MACHINE
Type E-600
The most perfect metallic threshing machine, equipped with exhaust pipe and feeder. This kind is also available for type D-400 and F-800



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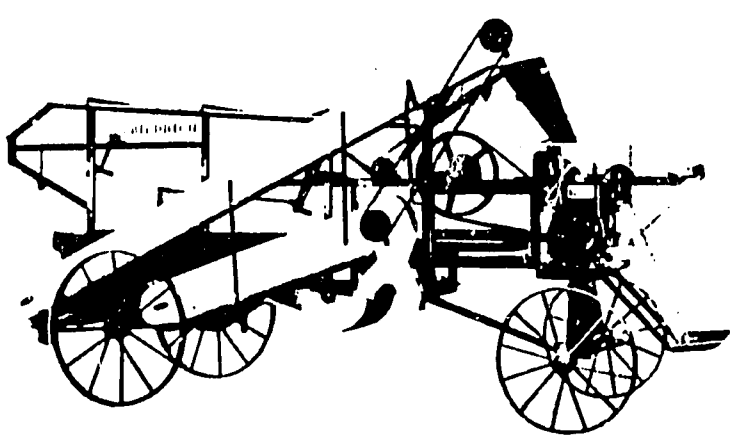
FRIEDRICH THRESHING MACHINE
Type C-300
Equipped with husk exhaust-pipe vacuum and tire wheels, this kind is also available for type B-200 and E-600



TRILLADORA FRIEDRICH Tipo A-100.
Equipada con motor en posición de trabajo. Este modelo viene también en los tipos B-200 y C-300.

FRIEDRICH THRESHING MACHINE
Type A-100
Equipped with engine in working position. This kind is also available for type B-200 and C-300

Figure 7

DIVERSOS TIPOS Y PRINCIPALES CARACTERÍSTICAS DE LAS TRILLADORAS FRIEDRICH
VARIOUS MODELS AND PRINCIPAL CHARACTERISTICS OF THE FRIEDRICH THRESHING MACHINES
DIVERSOS TIPOS E PRINCIPAIS CARACTERÍSTICAS DAS TRILHADEIRAS FRIEDRICH

MODELO MODEL MODELO	PROD. DE LOS SEGUIENTES CEREALES (Kg/HORA) PROD. OF THE FOLLOWING CEREALS (Kg/HOUR) PROD. DOS SEGUINTES CEREAIS (Kg/HORA)					PESO DE LAS TRILLADORAS WEIGHT OF THE THRESHING MACHINES PESO DAS TRILHADEIRAS			TAMAÑO cm SIZE cm TAMANHO cm		CANTIDAD DIENTES QUANTITY FANGS QUANTIDADE DENTES		ROTACIONES ROTATIONS ROTAÇÕES						FUERZA MOTRIZ-HP HORSE POWER-HP FORÇA MOTRIZ-HP		
	TRIGO SORGO SOYA WHEAT SORGHUM SOYBEANS TRIGO SORGO SOJA	ARROZ RICE ARROZ	MAÍZ CORN MILHO	FRIJOL BEANS FEIJÃO	AVENA CENTENO LINO OATS RYE FLAX AVEIA CENTEIO LINHO	SIN EXAUSTOR WITHOUT EXHAUSTOR SEM EXAUSTOR	CON EXAUSTOR WITH EXHAUST COM EXAUSTOR	CON EXAUST Y ALIMENT WITH EXHAUST AND FEEDER COM EXAUST E ALIMENT	ANCH. CILINDRO CYLINDER BREADTH LARGURA CILINDRO	ANCH ZARANDAS SIFTERS BREADTH LARGURA PENEIRAS	CILINDRO CYLINDER CILINDRO	PEINES COMBS PENTES	TRIGO LINO ALPISTE WHEAT FLAX BIRD SEED TRIGO LINHO ALPISTE	CENTENO AVENA RYE OATS CENTEIO AVEIA	ARROZ SORGO RICE SONGHUM ARROZ SORGO	SOYA SOYBEANS SOJA	MAÍZ CORN MILHO	FRIJOL BEANS FEIJÃO	SIN EXAUSTOR WITHOUT EXHAUSTOR SEM EXAUSTOR	CON EXAUSTOR WITH EXHAUST COM EXAUSTOR	CON EXAUST. Y ALIMENT. WITH EXHAUST AND FEEDER COM EXAUST. E ALIMENT
A-100	500	750	1.000	500	500	500	—	—	36	49	36	39	1.300	1.250	900	850	800	450	8	—	—
B-200	1.000	1.500	2.000	1.000	1.000	760	930	—	44	58	51	49	1.200	1.150	850	800	650	400	11	15	—
C-300	1.500	2.250	3.000	1.500	1.500	940	1.150	—	52	68	76	56	1.050	1.000	750	700	550	350	14	18	—
D-400	2.000	3.000	4.000	2.000	2.000	—	1.170	1.500	58	78	88	66	1.050	1.000	750	700	550	350	16	20	23
E-600	3.000	4.000	6.000	3.000	3.000	—	1.550	1.980	70	98	104	80	900	900	650	600	450	300	—	26	30
F-800	4.000	5.000	7.500	4.000	4.000	—	—	2.250	80	110	120	95	900	900	650	600	450	300	—	29	34

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- qualidade e durabilidade
- funcionamento simples e perfeito
- acabamento esmerado
- máxima estabilidade e peso mínimo
- extraordinária capacidade produtiva.

Milhares de trilhadeiras até hoje produzidas comprovam que FRIEDRICH está realmente no trilho certo do progresso e do desenvolvimento.

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Figure 8

In Guatemala most machine threshing is done by small threshers very similar in design to the type used by the U.S. farmer at least 30 years ago. Most are imported from Brazil. The threshers are usually owned by cooperatives or by individual farmers who contract with their neighbors. These threshers cost from $3,200 to $10,000 depending on their size. The manufacturers' specifications for one of these threshers are shown in Figures 7a and 7b. One dealer stated that the small farmer in Guatemala who buys one of the threshers and does contracting work will usually pay for the machine in one or two years.

For the small farmer in Latin America who requires threshing machinery, application of small stationary machines such as the design by IRRI or the more conventional threshing machines such as the ones shown in Figure 8a may be technically and economically appropriate. The eventual widespread use of these threshers may require the development of manufacturing facilities and dealers, proper training on use and maintenance of the equipment, and the availability of parts.

D. Crop Storage

Crop storage is an aspect of crop production that is frequently not given adequate consideration. Estimates place on-farm crop losses in Latin America at 15 to 30 percent due to inadequate storage and drying facilities (GIDA/ALC, 1977). At the same time countries are spending scarce foreign exchange earnings to import feed grains. Field visits to small farms indicated that storage was a problem.

Crop storage may be accomplished on an individual farm basis or by a cooperative effort among a group of farmers. Of all the activities of the crop production cycle, storage most easily lends itself to cooperative organization. The methods described here for storage may be used for either individual or cooperative storage.

Crop losses may be related to one or more of the following factors (Hall, 1970):

1. chemical changes,
2. micro organism growth,
3. value of produce,
4. climate,
5. transport system,
6. cost and availability of labor,
7. cost and availability of sacks, and
8. incidence of rodents and insects.

Table 15 provides a summary (Hall, 1970) of the advantages and disadvantages of sack and bulk storage systems. All grain handling for both the small and large farmer was done by sack in the countries visited. It is expected that this will continue as long as inexpensive labor is available.

Table 15. Advantages and Disadvantages of Sack and Bulk Storage

Sacks	Bulk
Flexibility of storage	Inflexible storage
Partly mechanizable	Mechanizable
Slow handling	Rapid handling
Considerable spillage	Little spillage
Low capital cost	High capital cost
High operating costs	Low operating costs
High rodent loss potential	Low rodent loss potential
Reinfestation occurs	Little protection against reinfestation
Requires more labor	

Table 16 provides a summary of methods in tropical countries for individual storage. In general, all of these methods have elements in their design that lead to significant losses. It was found that a wide variety of storage methods are being used by the small farmer in Latin America. Maize on the cob was usually stored hanging from the ceiling in the house or piled in the crotch of a tree and covered with palm or banana leaves. When shelled, maize is stored in many different types of open or closed containers. These containers include washtubs, metal drums, jars, and even specially fabricated closed metal bins.

A summary (Hall, 1970) of the methods used for central or cooperative storage is as follows:

1. storage in bulk on the ground or on special surfaces with no cover,
2. storage in bulk in silos or warehouses,
3. storage in bulk in special containers,
4. bag storage covered with plastic or tarpaulin, and
5. bag storage in buildings.

Certainly the methods that provide only minimum weather, rodent and insect protection lead to large losses. Even when permanent buildings or silos are used, losses will be significant if the building is not adequately designed.

The following criteria provided by Hall (1970) should be considered in designing storage facilities:

1. the structure should be entirely weatherproof,
2. the structure should be gastight to enable fumigation,
3. the structure should have controllable ventilation so that both temperature and humidity can be controlled,

Table 16. Traditional (or Producer) Storage Methods

Storage Method	Special Measures	Product
WITHOUT COVER		
No structure	Heaped on ground	Paddy Groundnuts
Vertical pole	Tied to poles	Maize
Horizontal cords or creepers	Hung on these strands which are tied between poles or trees	Maize
Vertical racks	Hung on horizontal poles fixed to vertical poles	Paddy
Platform (timber and grass)	Heaped on platform	Maize Pulses Groundnuts
Open baskets (grass)	Raised 1 metre or more above ground	Paddy Maize Groundnuts
Sacks (woven plant material)	Placed on platform 1 metre high	Paddy
WITH COVER		
Horizontal grid	Hung on horizontal poles; covered with loose thatch roof	Paddy
Platform	Heaped on platform; covered with "straw hat" which rests on platform	Paddy Maize

Table 16. (continued)

Storage Method	Special Measures	Product
Granary		
(a) Simple type (usually cylindrical	Constructed of plant material raised above ground, with thatch roof	All types
(b) Structure incorporating clay	As (a) but with mud or clay worked into floor and walls	All types
(c) Wall of clay mixed with plant material supported by timber frame	Cylindrical or elliptical, raised above ground	Cereals Paddy Millet Sorghum
(d) As (c) but not supported by timber frame	Jar-shaped, raised on "foot" of clay or log. Sometimes divided into compartments.	Maize Sorghum Millet
(e) Wall of clay only	Various shapes, "straw hat"	Cereals Groundnuts
Clay jar (usually kept in living hut)	Sealed with damp earth; sealed with flat stone and clay; partially baked before storage; produce mixed with ash, jar sealed with clay; produce mixed with ash.	Maize seed All types of grain Maize meal Maize Sorghum
Gourds	Sealed with clay Plugged with stems of plant	All types Maize Grain

Table 16. (continued)

Storage Method	Special Measures	Product
Baskets	Usually placed in kitchen	Groundnuts Paddy (seed) Beans
Commodity wrapped in matting	Kept in living hut	All types
Stored under roof of living hut	Small bundles hung from roof above fire	Cereals
Stored on floor of living hut	Temporary storage	Paddy
Underground storage	Sometimes lined with cowdung and fired. Opening sealed with clay or grass thatch and thorns.	Cereals
Communal store	Large crib of millet stalks or bamboo (12-ton capacity)	Paddy
"Improved traditional"	Square sided crib with timber frame and walls of wire netting	Maize

Source: Hall, D. W. 1970. Handling and Storage of Food Grains in Tropical and Subtropical Areas. FAO Ag. Dev. Paper No. 90, FAO, Rome.

4. the structure should be rodent and bird proof,
5. the structure should not have ledges and corners where dust and produce can lodge,
6. the roof of the structure should minimize the heat load, and
7. the structure should permit incorporation of fans in the walls and ducts in the floor for special bulk storage requirements.

Most of the small farmers in Latin America grow fruits and vegetables requiring marketing immediately following harvest. Thus, storage of fruits and vegetables by the small farmer does not appear feasible, except for products such as potatoes. Excessive losses of potatoes occur every year because of the lack of storage facilities. It would also appear that many fruits and vegetables grown might be sun-dried, stored as dried fruits and vegetables and then marketed or consumed by the farmer. Drying of fruits or vegetables was not observed during the field mission.

The storage of grain for seeds is of importance to agricultural development. A modern seed processing and storage plant was visited in Palmira, Colombia. The plant which included cold storage appeared to be well designed and operated. It is one of the main seeds plants in Colombia. It is known, however, that small farmers hold seed from one crop for planting the next crop and that this process leads to poor quality seed and to disease problems.

In summary, it was evident that there is a need to promote the proper storage of foods. The financial requirements for on-farm crop storage by the small farmer may be minimal and the storage technology exists in other parts of the world.

E. Summary

The purpose of this section is to summarize the previous sub-sections on the technical aspects of mechanization for the small farmer in Latin America.

It was pointed out that tillage requires the highest energy input of The various phases of annual crops production. Therefore, tillage and tillage equipment has received prime consideration in this report. It was pointed out that most tillage work by the small farmer is done by hand with a hoe. Only a few small farmers in Colombia, Costa Rica, Guatemala and Honduras own or otherwise have access to tractors and other powered primary tillage equipment. Although the use of rotary tillers appears technically feasible for many small farmers, their economic feasibility is doubtful, particularly on an individual farmer basis. In this regard, there is a need to evaluate the performance of foreign made rotary tillers in the Latin American context. Also the feasibility of "local" design and production of rotary tillers needs to be examined. The successful introduction of rotary tillers will also require farmer training in operation and maintenance of the equipment, and the establishment of reliable parts and repair service.

The development of irrigation practices are related to the availability of water and terrain. In relatively flat terrain, the main requirement is a small gasoline or diesel powered pump. If the soil type will allow furrow

irrigation, no further investments will be required. If furrow irrigation cannot be practiced, inexpensive plastic pipe can be used in most situations. The major investment required is the pump. The farmer should be trained on how to operate and maintain the engine and parts must be made available.

Grain crops are the main type grown by small farmers which can be harvested mechanically. Stationary threshers appear to be technically feasible for small areas. However, their economic feasibility has not been established. Major considerations in promoting the use of harvesting equipment include the development of indigenous manufacturing facilities, establishment of dealerships, farmer training, and the availability of parts.

Small farmers lack adequate crop storage facilities. The technology is available, requires minimum investment, and very little training to operate or maintain. However, the successful introduction of storage facilities requires an education program to demonstrate the advantages of storage to the small farmer, and in many cases, to provide simple plans on how to construct a proper storage facility.

The successful use of the tillage, irrigation and harvesting equipment described above requires that small farmers are trained in the operation and maintenance of small air-cooled, diesel, and possibly alcohol engines. In addition, the farmer must have quick access to suitable parts at reasonable prices as well as adequate fuel and oil supplies.

One conclusion of this study is that there is a need to evaluate the potential for developing indigeneous industries to produce agro-mechanical equipment for small farmers in Latin America. Indigenous industries may generate a number of benefits including saving scarece foreign exchange and generating new jobs. Of equal importance, indigeneous industries might be more responsive to the needs of small farmers in designing equipment for local topography and climate. Finally, small farmers will have greater access to repair parts if they are produced locally.

F. Promoting Development of Agro-Mechanical Technologies for Small Farmers

With the above considerations in mind, the following major steps are recommended in considering the development of agro-mechanical technologies for the small farmer in Latin America. It should be recognized that other elements such as the interaction of social and economic factors, and government policies also play an important part in the development and adoption of new technologies.

1. Determine, on a world-wide basis, the availability of agro-mechanical technology both past and present which might be applicable to the small farmer in Latin America.

2. Evaluate the technical and economic feasibility of these technologies for selected crops and regions in Latin America.

3. For those technologies that appear feasible, text them under controlled field conditions.

4. For those technologies that show economic as well as technical promise, build several prototypes for testing by selected farmers.

5. With a proven technology develop the engineering plans and seek out industry to manufacture the technology. Work with the manufacturer to be sure that the technology is build to specifications.

6. Assist industry in developing dealers for sales and parts.

7. Develop a training program, independently or in conjunction with dealers, for the farmer on how to operate and maintain the technology.

IV. Conclusions and Recommendations

Most, if not all, Latin American countries are being challenged to find solutions to the problems of (1) increasing food production, (2) creating more employment opportunities, and (3) reducing income and wealth disparities. This study has sought to provide a preliminary evaluation of the contribution that agro-mechanical technology has and can make toward resolving these problems.

More specifically, this study has sought to evaluate the actual and potential role of selected agro-mechanical technologies for increasing the productivity of the small farmer in Latin America. Although the focus of this study has been on the use of tractors and auxiliary equipment in primary and secondary tillage, other phases of agricultural production have been considered, i.e., harvesting, irrigation, and storage.

The procedure followed in this study has been to (1) review available literature on agricultural mechanization in Latin America and (2) make field visits to four countries--Colombia, Costa Rica, Guatemala and Honduras--to observe the extent, the nature, and the consequences of agricultural mechanization.

A. Conclusions

A number of conclusions can be drawn from the work to date:

1. Tractor use is confined mainly to the large commercially oriented farms, while most of the region's agricultural population still works the land with hand tools and animal-drawn implements. Tractor use is geographically concentrated in the fertile valleys and plains of a few countries. This geographical concentration occurs for a number of reasons: (a) much of the land in the region is mountainous and steeply sloped, i.e., land that does not lend itself to tractor use; (b) certain crops are more susceptible to mechanization than others; and (c) the vast majority of farm holdings are too small to make tractor use economical.

2. Although the region, in general, has a surplus of labor, and unemployment and underemployment are widespread, a number of factors have encouraged tractorization, including (a) government policies that distort factor prices, overvalue currency, and subsidize credit; (b) minimum wage laws and social security systems, although less effective in the countryside, have increased the cost of employing labor; (c) imperfections in rural labor markets contribute to seasonal labor shortages; and (d) the relative ease which large farms have in organizing the work of a few skilled tractor operators as opposed to large numbers of unskilled workers.

3. The principal effect of mechanization on agricultural production levels is achieved through expansion of the cultivatable land area, and multiple-cropping made possible by timely land preparation, cultivation and harvest.

Yield increases for a given plot of land arise primarily from the use of better seeds, fertilizer, pesticides, herbicides and water control. The greatest increases in agricultural production are likely to result from these and the selective use of tractors.

Although the evidence is limited and incomplete, it appears that selective use of tractors in the agricultural production phases of various crops and multiple cropping is not widespread in the region. To the contrary, it appears that large farmers are not taking advantage of their access to tractor power to intensify production.

4. Hand tools--the hoe and the machete--and animal drawn implements--the disc plow and the spiked-tooth harrow--are the principal forms of mechanical technology used by small farmers in the region. Although a few small farmers own tractors and auxiliary equipment, field visits to Colombia, Costa Rica, Guatemala and Honduras suggest this is not the case for most farmers. A number of factors contribute to the low level of tractor ownership among small farmers. Many small farmers in the region live in areas where the terrain is too steep to use tractors, and farm holdings are generally too small to make ownership of even the smallest tractors economical. In addition, high initial costs, limited access to credit, and unwillingness to take large capital risks discourage small size farmers from purchasing tractors.

5. Examination of cost and return data for tractors in the lower horsepower range (12 to 25 H.P.) indicates that a farmer must cultivate eight or more hectares to justify ownership of a small tractor. The majority of farmers in the region have land holdings of less than eight hectares. The downpayment on even the smallest currently available tractors in the region is 5-20 times greater than the small farmer's annual income. In addition, lack of operating experience, inability to make simple repairs, and difficulty in getting spare parts, contribute to the unprofitability of tractor ownership.

A few small farmers gain access to tractor services through rental agreements with a large farmer or with a cooperative. Presently the provision of tractor services via cooperatives is not widespread in the region, but appears to be growing in popularity. Several countries in the region either provide or are planning to provide publicly-supported tractor services through regional service centers.

6. Improvements in irrigation and on-farm storage appear to be of major importance in increasing small farm productivity. Water control can permit intensification of production through multiple cropping. On-farm storage increases the effective production level of the small farmer by reducing losses.

7. The development of indigenous industries to design and manufacture agro-mechanical technologies that are economically and technically appropriate for small farmers in Latin America may provide a number of benefits. For example, scarce foreign exchange could be saved; new jobs in the manufacture, distribution, service and repair of the machinery would result; the design of the machinery is more likely to conform to the topographical and climatic conditions of the region; and small farms would have greater access to repair parts and

and service. Presently Argentina, Brazil and Mexico are producing farm machinery (tractors, combines, etc.) for domestic use and export. The machinery, however, is designed primarily for larger farms. Investment in the production of small farm technologies is needed.

B. Recommendations

Given the preliminary nature of this study, it would be inappropriate, at this time, to recommend that the Bank establish specific policies or undertake major investments related to small farm agromechanical technology in Latin America without further investigation. In this regard it is recommended that the Bank conduct additional research in a number of areas.

1. Cost and return data for the use of tractors and other agro-mechanical technologies by small farmers is needed under alternative conditions, such as topography, climate, soil types, farm size, land tenure systems, and marketing systems.

2. Further research to determine the combined effect of selective mechanization and use of new seeds, fertilizers, and irrigation on small farmer income for different enterprises is needed.

3. The feasibility of establishing tractor-hire services should be examined carefully. The benefits and costs of private services vs. publicly supported service centers should be compared and analyzed.

4. Consideration should be given to the establishment of a regional testing center to evaluate the technical and economic appropriateness of agro-mechanical technologies for use by small farmers in Latin America, i.e., rotary tillers, stationary harvesters, irrigation equipment and storage facilities.

5. Opportunities for promoting the establishment of indigenous industries in the region to manufacture small farm agro-mechanical equipment should be examined.

6. An important aspect of any program to promote the development of agro-mechanical technologies that use internal combustion engines is the availability and cost of fuel and oil. The rising cost of fossil fuels pose serious problems for many countries. Research to determine the degree to which energy will be a stumbling block to any concerted efforts to promote the use of agro-mechanical technologies in Latin America should be undertaken.

7. To acquire a balanced view of agricultural mechanization in Latin America and the role it is playing in improving the productivity and general welfare of the small farmer requires that field visits be made to Argentina, Brazil and Mexico. The agricultural sectors of these countries are more mechanized than other countries, including those visited in the course of this study, Colombia, Costa Rica, Guatemala and Honduras.

8. A study of current agricultural mechanization policies for each Latin American country is necessary before the full technical, economic, and social consequences of those policies can be determined, and desired changes made.

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