MECHANIZATION ALTERNATIVES FOR THE MOST COMMON SIZES OF FARMS IN GUATEMALA

by

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INTRODUCTION

Guatemala is the northern most country of Central America. It is located between 14^{o} and 18^{c} north latitude and 89^{o} to 92^{o} east longitude. The Guatemala economy is based upon the export of agricultural products. The principal exports are coffee, cotton, sugar cane, beef and bananas.

Guatemala has undergone a rapid process of industrialization since 1960 when the Central American common market was founded. Despite that, agriculture still remains the largest employer of labor and is the first branching sector of the economy.

Guatemala has about seven million inhabitants. Of these, about sixty-five percent live in rural areas (Censo General 1979). Its total area is 108,889 square kilometers (45,452 square miles).

The physical features of the country are quite variable and are characterized by a south coastal plain where the best soils of volcanic origin in the country are located. They are very deep and fertile. The northern plains are characterized by very shallow sedimentary soils which do not adapt well to intensive agriculture. Between the plains there is an east-west mountain range which crosses the country from Mexico to the west and Honduras to the east. The soils are of volcanic origin, but difficult to farm because of the steep slope of the land. Part of this land is planted with permanent crops, such as coffee and rubber. Another part consists of natural forest. The rest is planted with annual crops such as maize and black beans which causes a very serious erosion problem.

The country is divided into three slopes: the Pacific slope, the Atlantic slope, and the Gulf of Mexico slope. The largest rivers flow northward to the Atlantic and to the Gulf of Mexico. Some of them are navigable by small boats. The rivers that flow to the Pacific are smaller and none of them are navigable.

The wind blows steadily from the north and insures a mild climate throughout the year, mainly in the mountain region. The daily and seasonal temperature variations are minimal, from about 10^{o} to $25^{o}C$. Precipitation is about 1000 millimeters per year. On the southern coast and in the northern region, temperatures can be as high as $35^{o}C$ with precipitation of about 3000 millimeters per year. There are two clearly defined seasons in the country. The rainy season occurs during the months of May through October and the dry season occurs from November through April.

Irrigation is practiced on part of the southern coast near Mexico and in the eastern part of the country, which is very dry. About 28.9 percent of the land is suitable for farming and is used for cultivation. Most of the remainder has slopes from sixteen to forty-five percent (Censos Agricolas 1964). Conservation measures must be used with permanent crops and it is almost impossible to produce clean, cultivated crops.

Guatemala has an unusual variety of soils. Most are of volcanic origin and these are the most productive. These soils are located on the southern coastal plains where sugar cane, cotton, bananas and grasses are grown. Guatemala's total land area if 108,889 square kilometers. About sixty percent of this area is hilly and mountainous.

The total exploited area amounts to 3,448,776.2 hectares. Of these, 995,253 hectares are crop land that covers 28.9 percent of the total, 1,051,946 hectares are grasses that cover 30.5 percent of the total and 810,648.7 hectares are forest that covers 23.5 percent of the total. The remaining 17.2 percent is land with no crops and land where the crops are lost (Censos Agricola 1964) (Tables 1 and 2).

This variety of climatic and topographical conditions leads to the production of a large number of different crops as shown in Table 3 (Censor Agricola 1964). About 525,964 hectares covering fifty-two percent of the crop land are used to cultivate maize, the principal cereal used for food in Guatemala. Following maize, the second largest cultivated crop is coffee which covers 231,646 hectares or twenty-three percent of the total crop land. Following that are cotton and sugar cane plantations.

As indicated, more than half of the crop land is used for the production of maize, a food crop. Because of the indigenous agricultural practices of the farmers, yields per hectare are very low and almost every year, corn and other food crops must be imported. Most of the food crops are grown on small farms without the use of new techniques. Therefore, modernization of the agricultural methods is needed to increase yield per hectare.

One important part of modernization in agriculture is mechanization. Farm mechanization in Guatemala has increased rapidly during the last few years. Evidence of this is that the number of tractors used in the last fifteen years has increased about eighty percent, from 3160 in 1964 to 14,093 in 1979 (Censor Agricolas 1964-1979). However, about eighty percent of the tractors are used on big farms which are involved in the production of export crops. On the small farms, where most of the food crops are grown, mechanization has increased very slowly. Alternatives need to be found in order to improve food production, mainly on the small and medium size farms. This could result in the improvement of the standard of living and reduce the poverty of the rural people in Guatemala.

Table 1. Estimation of the General Land Distribution in Guatemala

Land Use	Square Kilometers	Percentage
Total Area	108,889	100.0
1. Area used for cities, lakes, roads, other land and non-exploited land	74,465	68.4
2. Exploited land area	34,424	31.6
a. Land used in agriculture	14,473	13.3
b. Land used in grass production	10,500	9.6
c. Forest and other land	9,451	8.7

(Censos Agricolas 1964)

Table 2. Use of the Exploited Area for Permanent and Annual Crops

Land Use	Hectares	Percentage
Total exploited land	3,448,736.2	100.0
1. Grasses	1,051,946.0	30.5
a. Permanent cultivated grasses	544,422.9	15.8
b. Natural grasses	471,412.9	13.7
c. Semi-permanent grasses	36,110.2	1.0
2. Crops	995,253.0	28.9
a. Annual crops	675,833.2	19.6
b. Permanent and semi-permanent crops	319,419.8	9.3
3. Forest	810,684.7	23.5
4. Land with no crops	414,763.3	12.0
5. Land where the crops are lost	35,817.6	1.0
6. Other land	140,271.6	4.1

(Censos Agricolas 1964)

Table 3. Area Used for Each Crop

Crop	Hectares	Percentage
Total Area	995,253.0	100.0
Maize	525,964.0	52.85
Coffee	231,646.1	23.27
Cotton	85,428.7	8.58
Sugar cane	41,653.5	4.18
Wheat	22,901.9	2.30
Beans	19,490.1	1.96
Bananas	9,945.6	1.00
Rice	8,663.9	0.87
Lemon tea	8,347.5	0.84
Rubber	7,140.7	0.72
Plantain	6,103.3	0.61
Citronella	3,592.4	0.36
Potatoes	3,077.2	0.31
Pineapple	2,488.5	0.25
Sorghum	2,482.9	0.25
Tomatoes	2,473.8	0.25
Cacao	2,364.6	0.24
Oranges	2,298.1	0.23
Tobacco	1,610.0	0.16
Peanuts	500.5	0.05
Sesame	457.1	0.04
Broad beans	359.8	0.04
Kenaf	342.3	0.03
Henequen	336.0	0.03
Apples	251.3	0.02
Pears	213.5	0.02
Plums	175.0	0.01
Other crops	3,837.4	0.04

(Censos Agricolas 1964)

OBJECTIVES

The primary objectives of this report are:

1. To study and explain the current status of mechanization in Guatemala and give some alternatives for improving the standard of living and reducing the poverty of the rural people there.

2. To give some alternatives for mechanization of the small sized farms in Guatemala (less than seven hectares), where most food crops are produced by people with very low income.

3. To give some alternatives for mechanization of medium sized farms in Guatemala which include farms from seven to twenty-two and one-half hectares.

About ninety percent of the farms in Guatemala used only human labor and animal power in 1979 (Censos Agricolas 1979) while seventy-eight percent of the area cultivated in the developing countries in 1975 (FAO 1975) was farmed with hand tools and draft animal technology. Therefore, it appears that Guatemala is above the average in the use of hand labor.

Humans are not an efficient source of power, mainly because of the tropical climatic conditions of Guatemala (Gifford, R. C., 1981). Initially, efforts must be made to improve hand tools in order to make human power more efficient. Then, draft animal technology needs to be introduced and applied. In some situations, the introduction and application of mechanical power may be required. Increasing power alone will not solve the problems on the small farms; however, it must be done in conjunction with a general modernization of the farm. This would include the introduction of other technology, knowledge, and motivation, as well as the provision of institutional and infrastructural arrangements which would insure a receptive environment for technological changes.

DIFFERENT SIZES OF FARMS IN GUATEMALA

There is a wide range in the sizes of farms in Guatemala. Some are less than one hectare. These constitute about 60.5 percent of the total while covering only 4.14 percent of the total cultivated area. There are a few farms that are greater than nine thousand hectares.

Farm size in Guatemala has been decreasing year by year because of the custom of the division of farms by parents among their sons. This has resulted in the formation of very many micro-farms. About 89.7 percent of the farms consist of less than seven hectares and account for 16.05 percent of the total crop land. About 96.3 percent of the total number of farms are less than 22.5 hectares and cover about 27.7 percent of the total crop land. For the purposes of this report, farms with less than seven hectares are designated as small farms and those between seven and twenty-two hectares are designated as medium sized farms. The remainder of the farms which cover about seventy-two percent of the cultivated land are divided in different sizes as shown in Table 4 (Censos Agricolas 1979). These account for about four percent of the total number of farms.

In this report, greater emphasis will be given to the study of the small farms (subsistence farms), with some emphasis given to the study of medium size farms.

The subsistence farmers have been virtually forgotten by the government and by some international institutions. They cannot get credit because they do not have enough land to secure the loans. They cannot use new technology such as improved varieties, fertilizers, or new and improved tools because they do not have the money to buy them. In some cases they do not know they exist because the government extension programs do not provide them with the information. Since they do not produce export crops, they do not have the advantage of special infrastructures, such as roads. In some cases, they produce only subsistence crops for the immediate family. Many subsistence farmers and their families work only in the rainy season because in most cases, they do not have irrigation. They then must migrate to the coffee and cotton plantations to work for about four months in the harvesting of these products. An analysis of data from the FAO 1970 World Census of Agriculture, carried out by FAO and the World Bank, confirms the heavy preponderance of small farms in most developing countries. These data also indicate that the number of landless agricultural laborers is probably greater than hitherto realized.

The census states, "It appears that farm size in the developing countries is becoming smaller due to population pressures and/or official action." It adds, "For the near future it must be accepted that the small farm enterprise in developing countries is essentially a permanent institution. The long term solution to the problem of food, development and poverty must, therefore, be sought in improving the productive capacity of small farms and landless laborers and providing additional off farm employment for much of the rural labor force."

Table 4. Number of Farms and Distribution of Land According to Size of Farm in Guatemala

Size of Farm	Number of Farms	Percentage of Number of Farms	Area in Hectares	Percentage of Total Area
Less than 1.4 hectares	369,291.0	60.5	174,404.24	4.14
1.4 to 3.5 hectares	127,049.0	20.8	265,738.66	6.31
*3.5 to 7.0 hectares	51,234.0	8.4	238,165.07	5.60
**7.0 to 22.5 hectares	40,084.0	6.6	494,179.56	11.74
22.5 to 45.0 hectares	9,089.0	1.5	281,903.06	6.70
45.0 to 450 hectares	12,298.0	2.0	1,273,847.30	30.27
450 to 900 hectares	860.0	0.14	522,336.90	12.41
900 to 2250 hectares	383.0	0.06	494,884.61	11.76
2250 to 4500 hectares	73.0	0.01	220,626.72	5.43
4500 to 9000 hectares	15.0	-	85,444.79	2.03
Greater than 9000 hectares	6.0	-	156,333.10	3.71
Total	610,346.0	100.00	4,207,864.00	100.00

(Censos Agricolas 1979)

*About 89.7 percent of the farms are less than 7.0 hectares. These cover about 16.05 percent of the total area.

**About 96.3 percent of the farms are less than 22.5 hectares. These cover 27.79 percent of the total area.

PRESENT STATUS OF FARM MECHANIZATION IN GUATEMALA

In general, the farm mechanization in Guatemala improved between 1964 and 1979, which is the latest data available.

Table 5 (Censos Agricolas 1979) shows the extent to which the various forms of power are used in Guatemala.

Table 5. Types of Farm Power Used in Guatemala in 1979

Total Number of Farms	Tractors or Mechanical Power	Animal Power	Animal and Mechanical Power	Human Labor
528,792	27,142	25,929	16,236	459,485
Percentages of Use of Various Types of Power				
100	5.13	4.90	3.07	86.89

According to FAO source estimates, seventy-eight percent of the area cultivated in the developing countries (excluding China) in 1975 was farmed with hand tools and draft animal technology. In contrast, mechanical power technology was used on eighty-two percent of the area cultivated in the developed nations (FAO, 1970).

Table 6. Area Cultivated with Three Power Sources in 1975 (Area in Millions of Hectares)

Categories of Countries	Area Covered	Total	Power Source: Hand Labor	Power Source: Draft Animals	Power Source: Tractors
Developing Countries	Area	479	125	250	104
	% of Share	100	26	52	22
Developed Countries	Area	644	44	63	532
	% of Share	100	7	11	82
World Total	Area	1,123	169	313	611
	% of Share	100	15	28	52
(Excluding China)					

From Table 5 it can be seen that about eighty-seven percent of the power in Guatemala is human power and only 4.9 percent is animal power. Most developing countries are ahead of Guatemala in their use of animal and mechanical power, according to Table 6.

Another important factor is the ownership of machinery. According to Table 7, more than half of the machinery used on farms is rented by companies and the hire and custom tractor system is used. However, the companies have machinery that is appropriate only for big farms and the cost of rental is very high. The machinery is used for land drainage and other extensive practices. This hire and custom tractor system is not used for small and medium sized farms.

Table 7. Machinery Ownership in Guatemala

Total Number of Farms Using Machinery	Own Machinery	Rent Machinery	Own and Rent Machinery
57,310	27,233	28,871	1216
100.0%	47.52%	50.37%	2.12%

(Censos Agricolas 1979)

As was mentioned before, industrialization has improved in Guatemala in the last fifteen years. There has been an increase in numbers of all types of machines with the exception of electric generators. These decreased in number because more farmers are now under the national electrification plan.

From Tables 8 and 9 (Censos Agricolas 1964-1979), we can see increases as high as three hundred percent or more in tractors and combines, about two hundred percent in planters, pickups and jeeps, and more than one hundred percent in other machines or equipment, such as iron plows, theshing machines, mechanical harvesters, cultivators, and trucks. We can also see an increase of only thirteen percent in draft animal wood plows. This implies that draft animal technology has been more or less static.

To study this phenomenon of mechanization increase, we will divide the country into different geographical zones, as shown in the map (Fig. 1), in order to see what sizes of farms are getting the mechanization benefits. The division will be: central region, southern region, western region, northern region, and eastern region. Most of the big, export crop farms are located in the southern and part of the western regions. In 1964, these regions combined had about 81.5 percent of the total number of tractors, about 49.1 percent of the total number of iron plows, and about 82.6 percent of the total number of planters. They had only 1.9 percent of the draft animal wood plows (Censos Agricolas 1964).

On the other hand, the central, eastern, and part of the western zones had only 15.1 percent of the total number of tractors, about 13.3 percent of the total number of planters, but had about sixty-four percent of the total draft animal wood plows. Most of the small and medium sized farms are located in these three regions. Data are unavailable for 1979, but it can be assumed that the introduction and increase of mechanization have taken place in the big and medium irrigated farms and not in the smaller ones.

Attempts to clear the forest land and make it suitable for farming have been made since 1970, but these attempts have been mostly unsuccessful, due to lack of proper planning.

In summary, we can conclude that most of the high income, export crops produced on large farms have been cultivated using modern technology with improved and imported mechanization equipment. Problems remain in the mechanization of certain specialized operations such as the harvesting of coffee, cotton, and tobacco.

On the other hand, small farmers continue to use the centuries old indigenous methods, producing low yields and suffering excessive soil losses due to erosion of the steep slopes they cultivate. Most of them continue to use human power and inefficient hand tools.

Table 8. Equipment and Vehicles, April 1964.

	Number
Gasoline, diesel and L.P. gas engines	3,714
Electric motors	1,300
Electric generators	1,490
Wood plows	38,092
Iron plows	5,675
Tractors	3,160
Threshing machines	428
Planters	782
Mechanical harvesters	265
Cultivators	1,648
Combines	99
Machinery for humid coffee processing	3,188
Machinery for dry coffee processing	1,677
Machinery for sugar cane processing	6,249
Trucks used on farms	1,355
Jeeps and pickups used on farms	2,080
Oxcarts and wagons	5,460

(Censos Agricolas 1964)

Table 9. Equipment, Machinery and Vehicles, 1979.

	Number	Increase in % 1964-1979
Gasoline, diesel and l.p. gas engines	6,126	165
Electric motors	3,489	168
Electric generators	1,133	-23
Wood plows (draft animal plows)	43,235	13
Iron plows (tractor drawn plows)	11,677	105
Tractors	14,093	345
Threshing machines	1,215	184
Planters	2,481	217
Mechanical harvesters	761	187
Cultivators	3,725	126
Combines	477	381
Machinery for humid coffee processing		
Machinery for dry coffee processing		
Machinery for sugar cane processing		
Trucks	3,471	156
Jeeps and pickups	6,712	223
Oxcarts and wagons	15,243	179
Harrows	8,480	
Hand threshers for corn	3,239	
Fumigation pumps	41,117	
Irrigation pumps	4,016	

(Censos Agricolas 1979)

Comparing the data from 1964 and 1979, we can see the increase in the use of equipment, vehicles and machinery. In most cases, it is more than one hundred percent, but in some cases involving the use of tractors, planters, and combines, the increase was more than two hundred percent or even three hundred percent.

1) Central region
2) South region
3) West region
4) North region
5) East region

Guatemala Map Divided By Regions

Figure 1

GENERAL MODERNIZATION OF THE FARM

An increase in yield per area is not dependent solely on mechanization. Mechanization is one of many factors that small and medium farmers need to use in order to increase production.

Infrastructure is one of the most important parts of the system. Most of the small farms are in the central and western regions. If a subsistence farm is to be changed to a commercial farm, better roads and transportation are needed to take products to the market. The government needs to provide better road systems in these areas.

Irrigation is another important factor in the developing of the small and medium farm. In some cases, it is possible to construct government irrigation projects, but in others, the farmers have to buy their own mechanical pump sets. Irrigation allows intensification and diversification of the cropping system. Then farmers are not dependent on rainfall as the only source of water and they are able to get two or three crops per year from the same land.

Development and introduction of new varieties of crops are two important aspects needed in order to increase yield. The new varieties have to be resistant to diseases and insects, mature early, and give a high yield per unit area. The Science and Technology Agriculture Institute (ICTA, 1978-1979) has developed new varieties of maize, black beans, rice, wheat, etc., which are adapted to these conditions. The principal problem is with their introduction. Most of the farmers do not experiment with the new varieties because they are unfamiliar with them or do not want to take the risk. The problem here is a lack of extension agents. There are too few people working in this field. Many demonstrations need to be performed in each region; if not, no one will plant the new varieties even though they are available.

Fertilizer is another means of increasing yield. Most of the small and medium farmers use a very small amount per unit area or do not use it at all because the chemical fertilizer is too expensive. In addition, sometimes the fertilizers have been used indiscriminately without soil analysis, causing problems and losses to the farmers.

Farmers need to learn how to conserve their natural resources, such as soil and water. A very serious problem in steep slope farms is erosion. It causes the loss of many tons of soil each year. Farmers with farms of this type need to take advantage of soil conservation practices. The use of a crop that covers the land after the main crop is harvested is important. Cowpeas or other plants that adapt well to the region can be used. Contour farming methods also need to be taught.

Many times, the farmers get a good yield per hectare, but it is lost after harvesting due to inadequate drying and storage facilities for the products.

In addition to the different inputs, appropriate mechanization technology that is suited to the conditions of the farms is needed in order to increase production.

MECHANIZATION ALTERNATIVES FOR SMALL FARMS
(LESS THAN SEVEN HECTARES)

The alternatives for small farms must be studied according to the actual status of these farms.

Introduction of Small Hand Machines or Tools

As mentioned before, the most commonly used farm power source in Guatemala is human power; therefore, special emphasis must be given to this type of power, even though it is inefficient. R. C. Gifford states, "Farming on the basis of hand tool technology seldom exceeds a subsistence level. The area that can be cultivated by a single family is limited; typically not more than two hectares." In another paragraph he states, "Humans are not an efficient source of power under the conditions which are typical of the developing countries. Then it is clear that power is the major constraint on increasing agriculture output of farming when using only hand tool technology. However, we have to give some alternatives for this source of power to increase its efficiency and to reduce drudgery." (Gifford, R. C., 1981).

Development or introduction of hand equipment and tools could be the way of attaining the above objectives. Tools devised in other developing countries could be tested and adapted for the conditions in Guatemala.

One of the new machines or tools utilized could be the new soy bean planted developed in Thailand (Khamsaeng, M., Vuthijumnonk, K., 1981). The planter was developed by the department of farm machinery. This is one way of applying appropriate technology in agriculture.

The planter started from a very simple type, consisting of only a small steel tube with handle in a plastic cone. It was improved by adding modern and appropriate mechanisms. Finally, the last version called Mae-Jo5 (Figure 2) was completed.

The advantages of the Mae-Jos planter are: 1) The seeds are uniformly released (about two to four seeds per hole), and 2) The farmer can work faster, it is more convenient, and more seeds are saved. He can plant 2000-2500 holes per hour.

Some precautions to be taken when using this planter are: 1) The planter should be used in conjunction with a digging machine, and 2) The seeds should be graded to more or less uniform size.

This machine could be used to plant maize in Guatemala after testing, adjustment and necessary modification. The maize is planted in rows and the distance between rows is about seventy-five centimeters and the distance between the holes within rows is about eighty centimeters, using two to four seeds per hole. We can conclude that the planter pattern is almost the same as that of the Mae-Jo5 planter. (Khamsaeng, M., Vuthijumnonk, K., 1981).

In the case of weeding, tillage, and cultivation, the most commonly used tool is the hoe. Modern materials need to be introduced to improve durability and cutting edges. Tool design must be modified to be more suitable for new crops, different types of soils, different types of tasks, and/or to reduce drudgery.

In the article written by Amir Ukham, there is an example of how a small rotary power weeder (Figure 3) has been used for weeding rice in some Asian countries. This weeder is pushed by hand, but uses a one horsepower engine as a power source. Rotary power weeder description: a one horsepower engine powers the weeding rotors through a gear reduction box. Light sheet metal shields protect the rice plant. The rotor uproots and buries the weeds; three to five rows are done at once. Only seventeen man hours per hectare are required (Ukham, Amir, 1970). A Japanese firm manufactures this implement.

This small machine could be introduced and tested for weeding maize, rice and wheat in the early stage of growth. This is a possibility for reduction of the drudgery of weeding, which is the second hardest task after tillage.

One of the better alternatives for the small farmers in Guatemala could be zero tillage. This farm system would conserve the natural resources of soil and water, reduce the drudgery of human labor, and could possibly increase yield per unit area in many cases. In addition, zero tillage could be a better system for the steep slope farms.

Wijewardane, in his work, emphasizes that prime environmental constraints to the small farmer's productivity in the tropics are: 1) Loss of fertility from heavy erosion after intense rainfall on exposed, tilled soils on undulating terrain, and 2) Weeds.

He adds, "Zero tillage is the only arable farming system presently known which resolves these constraints while also enabling a ten times increase in the small farm productivity without need for costly and complex tractorization. The cost of zero tillage is less than that of mechanized tillage. 1) Mechanized farming done with a contractor costs fifty dollars per hectare (subsidized). 2) No till farming today costs forty to fifty dollars per hectare (non-subsidized). 3) No till farming in the future should cost twenty-five dollars per hectare." (Wijewardane, Ray, 1980).

Locally manufactured, simple hand tools have now been developed to enable the small farmers to adopt this energy and time conserving system.

An example of this is the development of the job planter which J. Frost states was pioneered by the International Institute for Tropical Agriculture in Nigeria (Frost, J., 1980). This planter can be used for minimum or zero tillage methods. The system can be either a single unit used by hand or a rolling unit with several dibbers which can be pushed by hand or power driven. It has the advantages of being quicker, generally, than conventional hand planting and the rolling version provides more accurate seed spacing. The same planter, with some improvements, is presented by Charles F. Garmen, D.S. Nagambeki, and N. C. Navasero in their paper. They call this the rolling injection planter (Figure 4). It has been developed and tested by ITTA (Garman, C. F., Nagambeki, D. S., Navasero, N. C., 1982).

This planter punches holes in the ground and drops seeds at the same time. The main parts of the planter are the planter wheel assembly consisting of two hexagonal steel plates with six openers attached to it, and a center hub on which the metering roller fits (Figure 5).

The rolling injection planter has many technical and economic advantages which make it particularly suitable for the rough, tropical field conditions found in Guatemala and could be very useful for the small scale farmer.

First, the design of the planter is very simple and easy to understand, assemble, and/or adjust by the farmer. Secondly, the planter is very light (fifteen kilograms) and its mechanism of punching holes with openers as it plants reduces the force necessary to push the planter. Thirdly, due to its simplicity of design, the cost of each unit is very low, which makes it suitable for small scale farmers who operate one to five hectares of farm land. To apply the herbicide, both desiccant and pre-emergence spraying are done with a standar hand pumped knapsack sprayer with an application width of 1.5 meters.

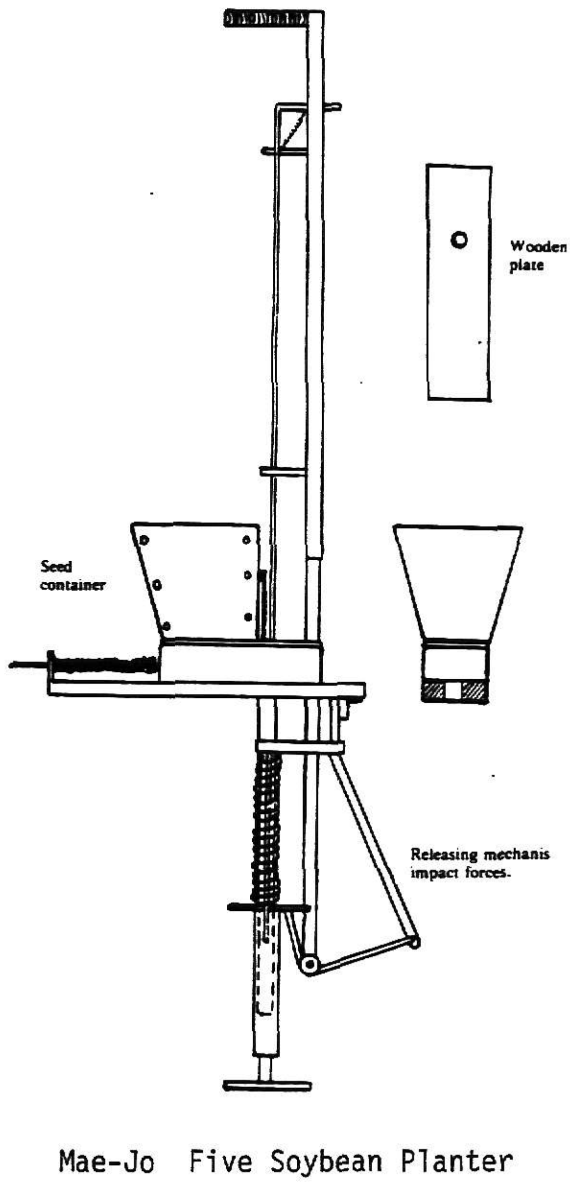
To apply fertilizer, the small farmer could use the hand pushed fertilizer band applicator (Figure 6). The fertilizer falls in a band on the ground from a spout on the lower right side of the applicator. The fertilizer is metered into a horizontal, tapered, coiled spring auger through an adjustable hole in the bottom of the hopper. (Garmen, C. F., Nagambeki, D. S., Navasero, N. C., 1982).

The introduction of hand threshers is important. There are some models manufactured and accepted in other developing countries which have been reported to be commercially viable products for different crops and conditions.

The transporting of the product from the small farm to the town or the home is very difficult when carried out by human power. The small farmer could use animal power or small hand carts.

Each of these hand tools must be introduced and tested for the specific conditions in Guatemala. After testing, the machines could be produced locally, thus developing small scale agricultural equipment manufacturing businesses.

The low income of the small farm has to be considered. On this depends the capability of the farmer to buy the equipment. The equipment has to be very cheap or it must be subsidized by the government for its introduction.

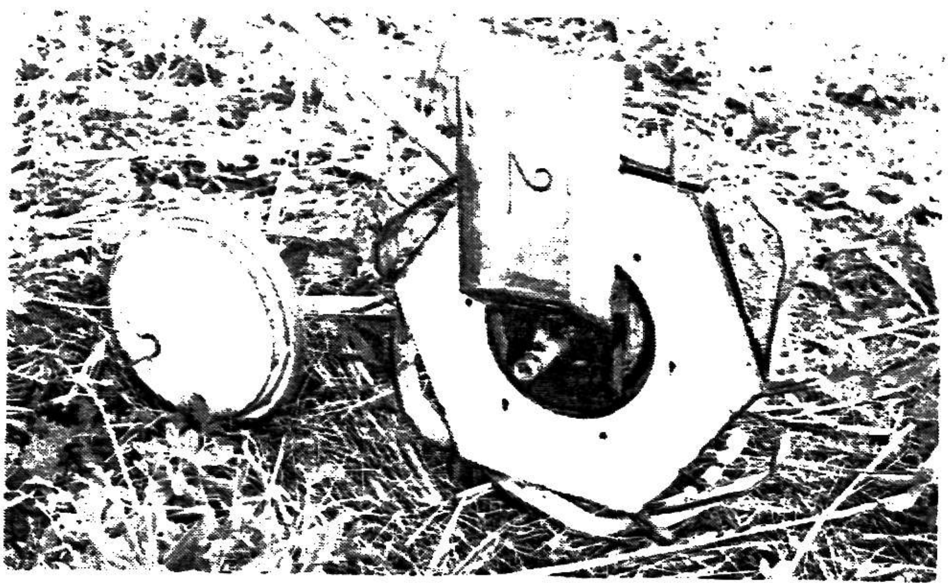


Mae-Jo Five Soybean Planter

Figure 2

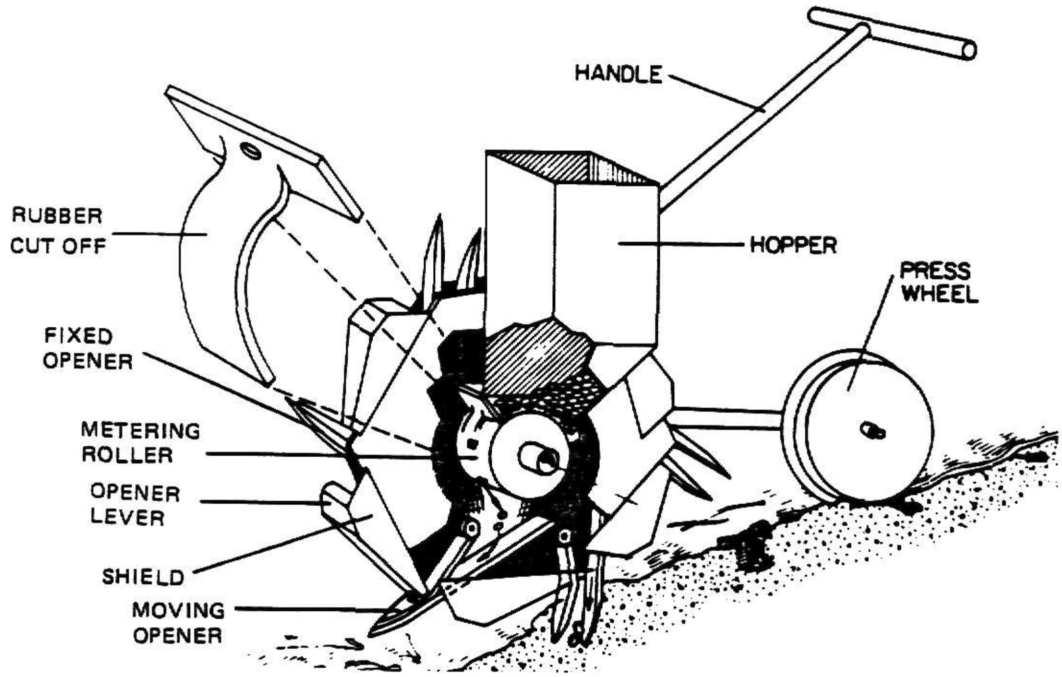
Small Rotary Power Weeder

Figure 3



Rolling Injector Planter

Figure 4



Rolling Injector Planter

Figure 5

Hand Pushed Fertilizer Applicator

Figure 6

Animal Power Equipment

Before giving the alternatives of animal power equipment, let us examine some of the pros and cons of the use of animal power.

According to R. C. Gifford, animals are inefficient converters of plant energy because large areas of land are required for their feeding. In addition, the keeping of animals for draft purposes is becoming increasingly uneconomical for farmers in many countries because the land is needed for the production of food for humans. Nonetheless, there are many areas where the use of animal traction is warranted and in which greater efforts are needed to improve and expand draft animal technology, particularly for the improvement of draft animal implements. (Gifford, R. C., 1981)

Other writers take a different view. Although agricultural mechanization has increased at a rate of one to one and one-half percent per year in developing countries (Coe, M. R. and McDowell, Robert E., 1980), draft animals continue as a major source of power. Hopfen (1969) estimated that nearly ninety-eight percent of the total agricultural power available in the People's Republic of China, Indonesia, Korea, and the Philippines was derived from animals. Of a total of forty-four million horsepower in India, draft animals provide twenty-eight million (sixty-four per cent) and hence are the dominant power source. Mechanical power provides only 4.1 million horsepower (9.3 per cent). (Raja Rao, R. J. S.)

In regions or countries where animal diseases and pests are a major problem, animal power is unsuitable. In Guatemala, animals supply about 4.9 per cent of the total power. Perhaps this source of power could be introduced and/or applied as the appropriate technology to small farmers when indigenous hand tool technology is not adequate to achieve goals of agricultural production.

Draft animal technology, therefore, has an important role to play in the effort to increase agricultural output in many regions and micro-environments around the world, particularly in Guatemala.

The principal draft animals used in Guatemala are teams of bullocks. Horses and mules are mainly used as pack animals. Therefore, the recommendations given here are for bullocks only.

A very important thing to be considered in the use of animal power is efficient transfer of power from animals to implements. The physical principles of line of draft, rolling, and grade resistance have to be considered. Improved harness would permit the generation of greater draft and would provide added comfort for the animals.

The frame for a pair of animals designed by Mr. Nowe-France of West Africa (Figure 7) would be an adequate frame to use. It has a multipurpose module for easy interchange of implements, and vertical adjustment (Figure 8). It is easy and cheap to construct. (Wanders, A. A., Steven, P., Gazo, Tarune, and Daywin, F., 1981)

For tillage operation, the small farmer uses a traditional wood plow. It has a metal point, but the moldboard is inadequate (Figure 9). It is difficult to cut all rizomes and to bury the weeds.

An alternative for primary tillage would be the six inch draft animal plow developed in West Africa (Figure 10) and presented by Wanders, Steven, Gazo and Daywin in their work. The improved metal design plow, with a well proportioned and sharp share combined with a normal cylindrical moldboard, gives a good cutting and turning of the soil layer. The six-inch plow developed in West Africa proved to be more effective in this respect, particularly when used under relatively wet conditions. To improve the controllability of the plow and to reduce the size of the clods produced, a vertical knife coulter welded to the share proved to be very effective.

Using work animals for plowing operations also reduced the labor requirements considerably, namely from 1700 to 610 man hours per hectare or about ninety man-days per hectare. This is one-third of the time required for complete manual clearing.

Another alternative to the locally made wooden plow is presented by R. C. Fisher. This is an improved buffalo plow with reduced draft so a wider plow can be used. It has been quite successful.

Characteristics: The moldboard plow has a larger radius of curvature. A more gradual altitude relative to the soil is obtained by rotating the moldboard and point twenty degrees clockwise about the longitudinal axis. The point suction is reduced in comparison with a plow manufactured in Khon Kaen. The depth is controlled at 127 milimeters (five inches) by using gage wheels and skids, respectively, in upland and paddy comparative trials. The average specific draft (kilograms per square centimeter of furrow slice) in three upland and four paddy tests was reduced thirty-nine and thirty-two percent, respectively, relative to the Khon Kaen plow. (Fisher, R. C., 1982).

A smaller moldboard, equivalent in size to the Khon Kaen plow, is intended for upland use. The total draft should be about sixty-five percent of the draft required by the Khon Kaen plow.

Geometric features:

Point suction angle 18°
True moldboard radius 20 centimeters
Approximate radius at middle of moldboard 38 centimeters
Altitude angle of moldboard 20°

An implement that could be used to clean and level the seedbed after plowing is the tooth harrow (Figure 11). However, it has proved to be less effective where wet and sticky soil conditions prevail.

IRRI has developed a two meter wide triangular land leveler, primarily for use with narrow row upland seeded crops. One pass prior to seeding is effective in leveling and some clod size reduction results. In a controlled test, the land development center at Lampang obtained forty-five percent higher wheat yield with a leveling operation prior to seeding. These implements could be tested in Guatemala.

Planting and seeding. These operations are done by hand on the small farms in Guatemala. To enable planting of crops in rows and to speed planting, a simple beam can be attached to the multipurpose Kanol frame. The beam is equipped with small furrow openers at the required planting distance (Figure 12). Dibbling of seed in these small furrows is done by hand with subsequent closing of the furrows using branches. The use of work animals for the opening of furrows reduced the total labor requirement considerably (thirty-two per cent). (Wanders, A. A., Steven, P., Gazo, Tarune, and Daywin, F., 1981)

An alternative for planting is the three row upland seeder which has been designed, constructed, and tested by IRRI. It is specifically engineered for use with animal power (buffalo). It is equipped with indicators to enable the operator to align it with the previous row as he walks along. It will accommodate three-twenty centimeter or two-forty centimeter row spacings.

Description: Seed plates for the IRRI designed upland seeder are available for rice, wheat, maize, sorghum, soybeans, mung beans, and peanuts. The plates are oscillated forward by an arm that can be readily aligned with two, three, four, or five lobe cams to provide fifty, thirty-three, twenty-five, or twenty centimeter spacing of seed drop in the row. The plates are returned by extension springs. The hopper has two compartments and each plate has two metering holes so fertilizer and seeds can be alternately dropped in the row. Seed metering is not satisfactory when using seeds with a wide variance of size, such as ungraded maize. By screening such seeds in two size grades and using an appropriate seed plate, satisfactory performance is obtained. (Fisher, R.C., 1982)

From the annual report of the CIAE (1980-1981), the two-row seed-cum-fertilizer drill (Figure 13) could be recommended for testing and introduction. An improved prototype was fabricated by making the following modifications in the design of this drill: 1) The seed metering mechanism was improved by using a rubber roller having grooves on its periphery for positive and accurate metering. 2) The fertilizer metering mechanism was improved by using a mild steel helical agitator with notches to aid free flow of the fertilizer. 3) The locations of seed and fertilizer boots were adjusted to maintain a lateral distance of about two centimeters between seed and fertilizer. 4) The orientation of boots was changed to avoid excessive bond in the delivery tubes for seeds and fertilizer. 5) For better stability, two ground wheels were provided instead of the one used in the early design. The improved design was tested for sowing soybeans, sorghum, black graham, green graham, and wheat with the following results: The field capacity was 0.08 hectares per hour and field efficiency was 72.45 percent. The draft requirement was 61.5 kilograms. The inter-furrow opener variation of seed was only 2.6 percent (Tomar, S. S., 1981).

Fertilizer applicator. An IRRI designed attachment called plow sole fertilizer applicator used for applying fertilizer during the plowing operation is available and could be tested in conditions prevailing in Guatemala.

Description: The fertilizer is metered, dropped, and covered by the next furrow. It is adaptable to plows pulled either by animals or power tillers. The plowing capacity is decreased by ten percent because of the necessity of stopping to fill the hopper. The plow-down replacement of application results in more efficient use of chemicals. This fertilizer applicator could be used for crops that require an early application of fertilizer and a subsequent application during the growing stage. (Fisher, R. C., 1982).

ICRISAT (Annual Report, 1979-1980) in India has been testing a fertilizer drill. This is based on the oscillatory principle shown in Figure 14. Function of the drill: The hopper is filled with dry fertilizer which flows down to the concave, filling the chamber in the process. During operation, the concave oscillates about the center. The construction is such that while the concave is moving away from the central position in either direction, the rake strip pushes the fertilizer outward, causing the fertilizer to spill over the edges of the concave. During the return stroke of the concave, the cavity created by the rake strip is filled with fresh fertilizer from the hopper by gravity flow. In each cycle, the fertilizer is dropped once from the front edge and once from the rear edge. The rate of fertilizer application can be varied by changing the angular displacement of the concave and/or the frequency of oscillation. Figure 15 shows a prototype of the four-row fertilizer drill mounted on a tool carrier.

Weeding. Traditionally, weeding is done by hand, using a relatively large hand hoe.

Draft animal weeding tines (Figure 16) for interrow weeding are presented by Wanders, Steven, Gazo and Daywin, but they have not been tested. In all cases, planting in rows is required. The reduction in labor requirements using this improved weeding implement might prove to be considerable.

An ox-drawn straddle-row weeder (Figure 17) developed at IAR could be tested and introduced for crops under furrow irrigation which are planted on the ridge. It has a performance output of 0.1 hectare per hour while the traditional method output is 0.02 hectare per hour, giving an output advantage over the traditional method of five hundred per cent. (Kaul, R. N., 1982)

These are the principal operations that can be done with animal power. The harvesting and threshing of the product could be done by hand threshers or mechanical powered threshers.

Transport. The carts being used at this time in Guatemala are wood carts with wood bearings and iron wheels which require more draft. They need to be improved by using rubber wheels and metal bearings in order to reduce friction.

One problem when draft animal technology is selected as the appropriate mechanization level is the need to insure that each small scale farmer has access to the animal power and improved implements.

In many situations, a farmer is unable to maintain a pair of draft animals. In Guatemala, the traditional method of acquiring draft power is by a neighbor-to-neighbor animal exchange system, where the animals exist.

In addition to the problem of animal power, the situation in regard to improved draft animal implements is changing rapidly. A few years ago, improved implements were within the reach of most small scale farmers, but now these implements are beyond the financial capability of many small farmers. At this time, the use of animal power in Guatemala is very low. As previously stated, it will be impossible for most small farmers to maintain a pair of animals or buy the new, improved implements. The government needs to implement a program for breeding, training, and selling bullocks, which are the draft animals used there.

Another possibility would be government introduction of animal power on the small farms through some form of multi-farm use of animal power and improved implements, such as cooperatives, government operated power stations, or the custom bullock system (hire bullocks).

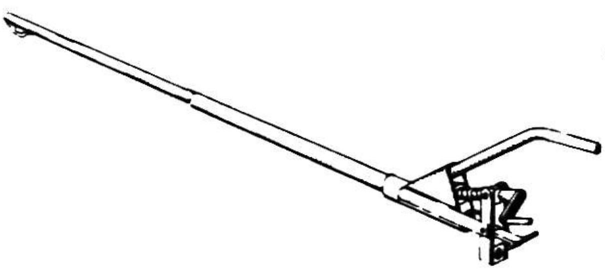
Government sponsored cooperatives. This form of support arrangement has been used in many developing countries and has been well suited to small scale farming.

In Guatemala, cooperatives could be established in two ways: 1) To provide animal power and implement services to members, and 2) To provide animal power and implements in conjunction with the provision of other inputs (fertilizer, certificate seed, pesticides). This could be a multipurpose cooperative.

Probably the latter would be the better alternative because, in addition to furnishing the source of power and equipment, important inputs would be provided that would increase the yield per unit area. The cooperatives would need to be sponsored by the government and provided with a manager with a high level of technical organization, an extension worker, and a veterinarian.

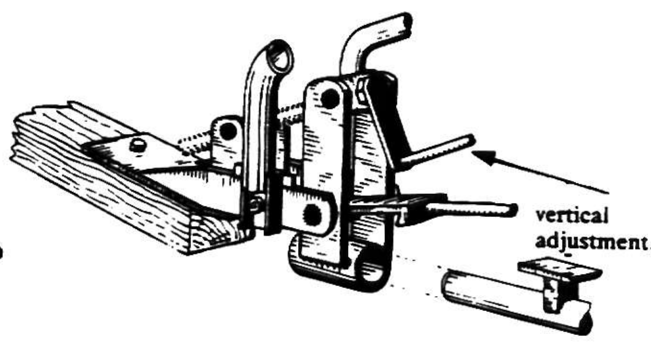
Government operated power station. This could be for the purpose of introducing the new equipment and the animal power where the use of them is almost unknown. The system would need to be government operated, at least for two to three years. Then, the equipment and animals could be sold to a specific farmer in the area who would be chosen as a possible bullock owner by the manager and extension personnel. This person would rent the animals and equipment to the other farmers in a determined area. In this way, the custom bullock system could be introduced.

Animal Power Equipment



Frame for one pair of animals

Figure 7

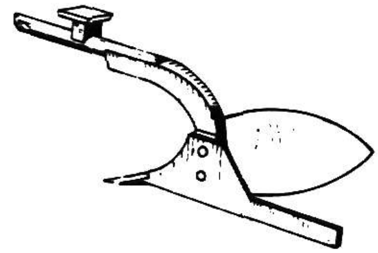


Multipurpose module for easy interchange of implements

Figure 8

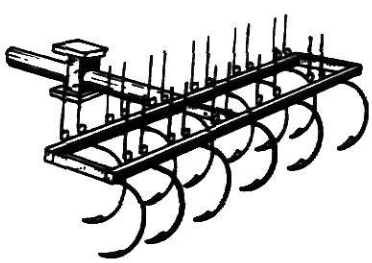
Locally made wooden plow
with metal point

Figure 9



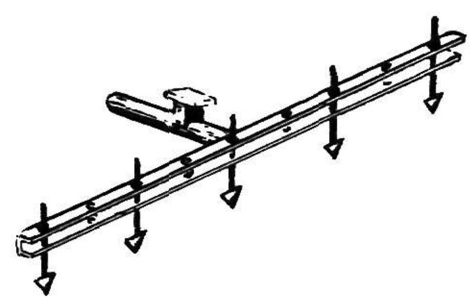
Improved design metal plow

Figure 10



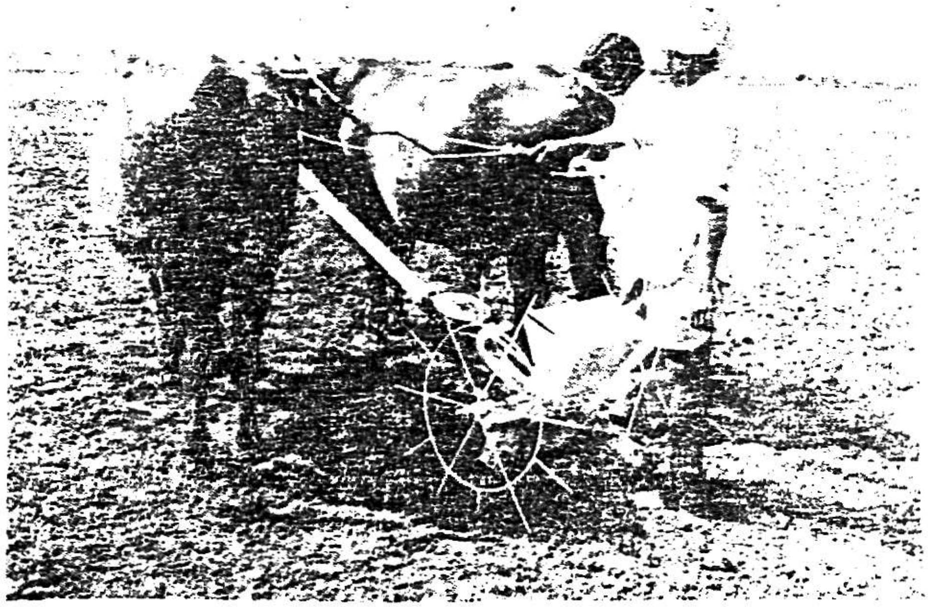
Tooth harrow and tine cultivator

Figure 11



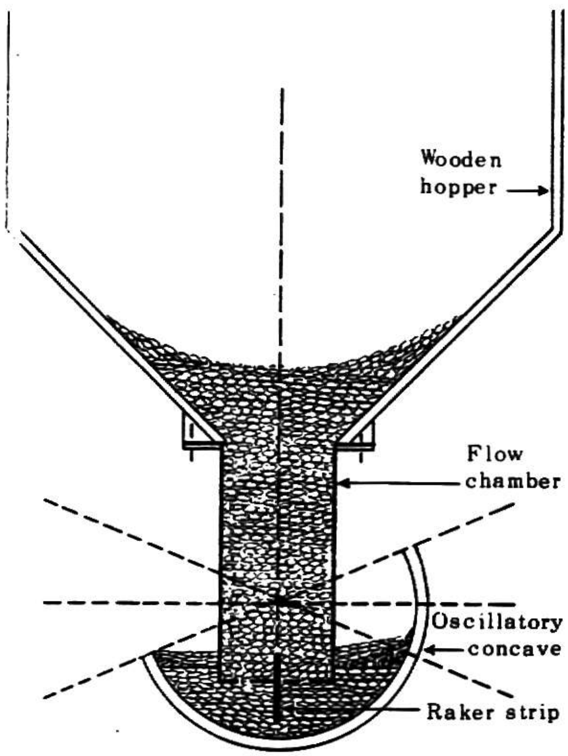
Furrow opener for hand seeding

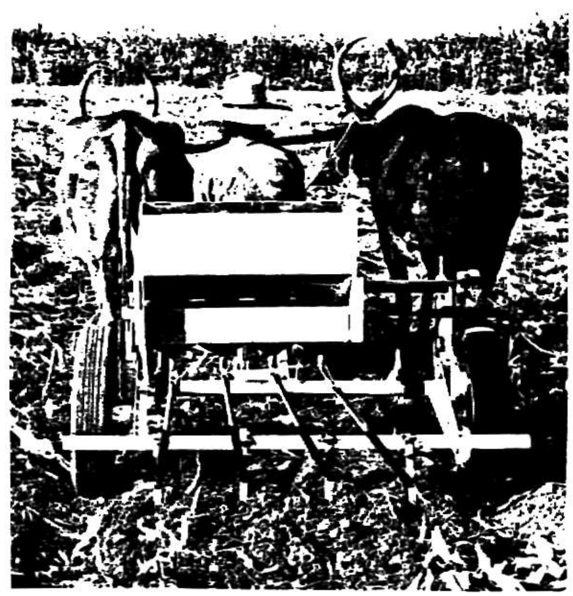
Figure 12



Two-Row Seed cum fertilizer drill

Figure 13

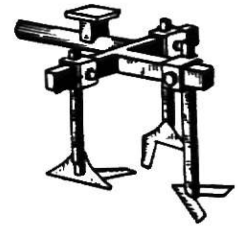




Fertilizer drill

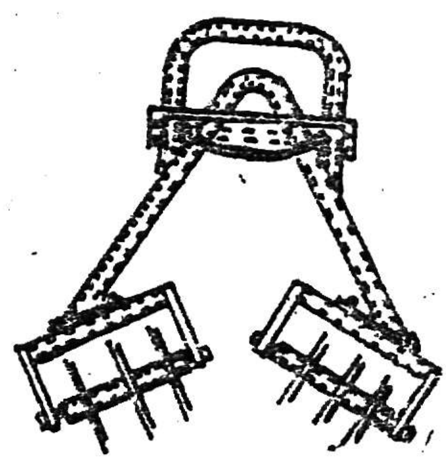
Figure 14

Figure 15



Inter-row weeding tines

Figure 16



Ox-drawn straddle row weeders

Figure 17

Mechanical Power Equipment
(Small Farms Less Than Seven Hectares)

Various kinds of mechanical power equipment have been developed and used effectively for small sized farms in the far east. Power tillers and single axle tractors with related implements are being used. .This is an applicable solution in those countries where this type of machinery is technically suitable (paddy crops), but may not be appropriate for the dry land conditions in Guatemala.

The principal problems in using machinery on the small farms are: 1) The small farms consist of scattered fields or plots. 2) They have limited access (roads, lanes, entrances, etc.). 3) The very low income of the farmers.

However, some tractors and equipment for the small farmers could be introduced and tested. A four-wheel tractor with about ten to twenty horsepower might be acceptable. The greatest problem in trying to provide mechanical power technology to the small farmer for exclusive use on a single farm unit is that the small farmer does not have sufficient income to buy a tractor or to obtain credit.

An economic analysis using an Agro Util seventeen horsepower tractor and the following equipment follows: (Agro Util Tractor)

Equipment
2-10" bottom plow
Disc - 52" width of cut (tandem)
Planter
Cultivator
(Figures 18-21)

Assumptions:

1. Eight year life of the tractor -- 3200 hours (400 hrs/year).
2. Considering the top small farm size as a unit, 7 hectares.

3. The crops cultivated by the small farmers are maize and black beans using only rainfall with a yield of one crop per year.

(See Appendix I for calculations.)

Total fixed cost/year (Tractor and equipment) . . .	$1257.48 -----	I
Total variable cost/year (Tractor and equipment) .	552.61 -----	
Adding I and II		
Total fixed and variable cost/year (Tractor and equipment)	$1810.09 -----	III
Total cost of inputs/year	1412.50 -----	IV
Adding III and IV		
Total cost of production per year	$3222.59 -----	V
Gross Income	3150.00 -----	VI

Gross Income (VI)	$3150.00
Total cost of production (V)	3222.59
Net Income	$ -72.59/year

The economic analysis shows:

1) The tractor and equipment are under used in the small farm (153 hours of use per year).

2) The net income is negative and a farmer could lose more in the case when market prices fluctuate.

3) The small farmer cannot afford to buy a tractor and equipment by himself.

Therefore, a more practical solution involving the use of small tractors by small farmers would be some form of multi-farm utilization of the power. This could be in the form of government sponsored cooperatives and government operated power stations, thereby establishing a custom tractor system in the same manner as explained for animal power.

The next economic analysis will show what area a small tractor could work, assuming that a maximum of fifteen days at ten hours per day is available for the plowing operation. (See Appendix II.)

Economic Analysis:

Total capacity of the tractor -- 22.55 hectares		
Total fixed cost/year (Tractor and equipment) . . . . same as for 7 hectares	$1257.48 -----	I
Total variable cost/year (Tractor and equipment) . .	$ 897.76 -----	II
Adding I and II		
Total fixed and variable cost/year (Tractor and equipment)	$2155.24 -----	III
Total cost of inputs/year	4149.22 -----	IV
Adding III and IV		
Total cost of production per year	$6304.46 -----	V
Gross Income	$9250.00 -----	VI

Gross Income (VI)	$9250.00
Total Cost of production (X)	6304.46
Net Income	$2945.54

$245.46/month
$143.34/hectare/year

This analysis shows:

1) The small tractor could be used efficiently for about 449 hrs/year, as the manufacturer recommends that it be used 400 hours per year.

2) The net income per hectare increases from a negative one to a low one but may be adequate income per year if 3 farms of about 7 hectares are cultivated as compared to a single 7 hectare farm.

3) This program of multi-farm use of power needs to be sponsored by the government because of the high investment required and the need for qualified personnel to administer the program.

4) The tractor and equipment could work with any size farm less than 7 hectares.

5) The tractor and equipment could be used in a private cooperative ownership group (family members or friends).

This tractor and equipment and other brands, such as the Self Helper developed in Iowa, are very simple machines. They could be easily adapted for local assembly in developing countries. Pakistan and Honduras are two developing countries where this tractor has been built and assembled.

The Iowa manufacturer gives the tractor a very good performance rating. The manufacturer claims it can plow from 1.2 hectares to two hectares per day pulling a thirty-centimeter plow eighteen centimeters deep at 5.6 kilometers per hour in hard plowing conditions in second gear. The tractor and equipment would have to be tested in Guatemala's conditions in order to be sure it would perform this well.

Specifications of the Self Helper tractor (Self Help 1976-1980):

Weight	385 kg
Length	2.06 m
Width	1.1 m
Wheel base	1.41 m
Ground clearance	36 cm
Pay load with trailer	1360 kg
Engine	7 hp
Speed up to	8.8 km/hr
Fuel capacity	8 litres

Fuel consumption approximately 1 litre per hour for farming operation

Agricultural implements:

Self Helper tractor with 7 hp diesel engine	$2800
12" moldboard plow	210
24" disc plow	250
Single disc with 12" blades	300
6 shovel cultivator	150
Planter with fertilizer	285
	$ 3995

Row crop/tree sprayer with breakaway boom and others

Figures 22 and 23 show the Self Helper tractor plowing and ridging, respectively. Figures 24 and 25 show the Agri Util tractor plowing and discing.

An Agri Util four-wheel tractor which develops a maximum of 12.5 horsepower at 3600 rpm and a Self Helper four-wheel tractor which develops 10.5 horsepower at 3600 rpm were evaluated at Kansas State University in 1974-1975. (Larson, G. H., Jensen, J. C., and Schield, W. L., 1976). They concluded: on the average, the equipment could be expected to plow about two acres per ten hour day (0.81 hectares per ten hour day). The discing operation varied from a high of 1.02 to as low as 0.96 hours per acre or ten acres per ten hour day (four hectares per ten hour day). Ridging was done at a rate as high as 2.50 hours per acre and as low as 1.79 hours per acre. Approximately five acres per ten hour day (two hectares per ten hour day). The average fuel consumption was 0.21 of a liter of gasoline for each maximum rated horsepower.

In general, it can be said that this class of tractor (10-14 hp) has ample power for the tillage tools used, but the limiting factor is wheel slippage when there is not enough weight on the traction member.

Forms of Multi-Farm Use of Power and Related Implements and Equipment for the Small Farm (Less Than Seven Hectares) in Guatemala

Essentially, for mechanical and animal power technology to be available to the majority of small-scale farmers, it must be through some form of multi-farm use of power and related implements or equipment.

One way of accomplishing this is to establish farmers' cooperatives. Cooperatives could be established specifically to provide machinery services to members. A multi-purpose cooperative which would provide other inputs (fertilizers, pesticides, seeds, etc.) in conjunction with machinery services would be even better. This type of cooperative has a better success record in many countries (Chancellor, William J., 1978). The success of a multi-purpose cooperative depends on the availability of managerial staff with a high level of technical and organizational ability.

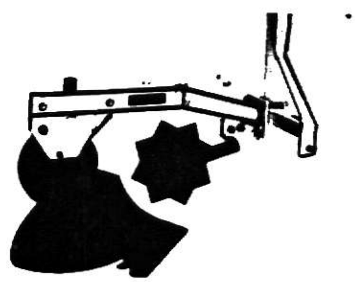
Government stations for custom operations. In this case, a government agency owns the machinery (or oxen team and equipment), operates and maintains it, establishes the rate for services, and may have a monopoly for providing services, at least for the first few years. The management and staff of each operating unit would be salaried employees. The objective of this scheme is to provide subsidized services to farmers and the rates charged would be, therefore, considerably below true costs. One of the problems with the scheme is that the system has to be operated under established governmental bureaucratic procedures which are often burdensome and restrictive in terms of the necessary rapid and flexible day to day operational decisions.

Another problem is the replacement of oxen teams and machinery since charges are inadequate to cover both fixed and variable costs.

However, this system could be used as an instrument for introducing the ideas of tractor and animal power use and contractor operation and ownership of machinery by informal and formal groups. As will be explained later, the system functions well for both small and medium sized farms, the difference being that different sized tractors must be used and that the small farms have to be government sponsored.

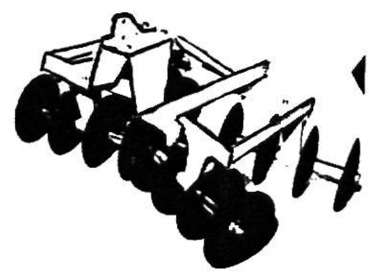
The custom tractor system operation. After the introduction of mechanization through government sponsored programs, it will be necessary for the government to increase the costs of services to a level of potential economic feasibility for private contractors. As farmers' demands exceed government station capacity and the government costs of services increase, private tractor contractors will be encouraged to go into business and the need for tractor station activities will diminish.

Agro-Util Equipment



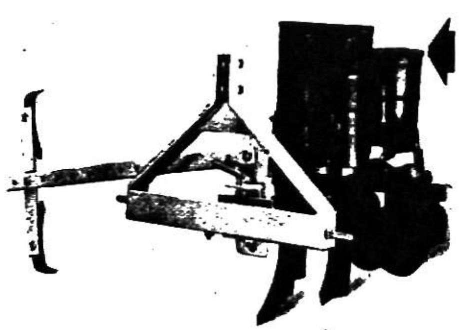
Rugged moldboard plow

Figure 18



Tandem disc harrow

Figure 19



Single row planter

Figure 20

Cultivator

Figure 21

Figure 22
Self Helper Tractor Plowing

Figure 23
Self Helper Tractor Ridging

Figure 24
Agro Util Tractor Plowing

Figure 25
Agro Util Tractor Disking

ALTERNATIVES FOR MEDIUM-SIZED FARMS (7-22.5 HECTARES)

Most of these farms are located in the eastern region as shown on the map. In this region, there is a shortage of man power, mainly during the peak periods of planting, weeding and harvesting. The hand power is scarce and when found, relatively high wages have to be paid.

Here, many government irrigation systems have been developed and other farmers have their own pump sets or wells which are used to intensify the agriculture.

The farmers in this region grow maize and beans, but in addition, they grow higher income crops such as tobacco, tomatoes, onions, watermelons, etc. Most of these farmers get at least two crops per year, so their time to do tillage and other practices is very limited.

Until ten or fifteen years ago, animal power with some improved wooden moldboard plows had been used for tillage, but since that time, there has been a high increase in the use of mechanical power. The problem is that the tractor in use has been between forty and seventy horsepower. The companies introduced this size of tractor and equipment without any economic analysis. In most cases, the tractors are underutilized, being used only for the primary and secondary tillage throughout the year. Recommendations for the efficient use of this tractor will be made later in this report.

One possibility for these farms would be the introduction of the small four-wheel, ten to twenty horsepower tractor. This size tractor could be tested and an economic analysis would show whether or not its use would be practical.

The Agro Util seventeen horsepower tractor with the following equipment might be a possible alternative.

12" moldboard plow or 2-10" bottom plow
Tandem disc harrow -- 52" width
48" cultivator
Furrower/ridger
Single row planter
Irrigation pump
2-ton capacity trailer

An economic analysis was done with this tractor on the small farm using maize and beans as crops. The results show that the tractor could be used effectively in a multi-farm system. It would work efficiently on twenty-two hectares of land with only one crop per year.

The following economic analysis using maize and black beans as crops shows the estimated cost analysis per year for a medium sized farm (seven to twenty-two hectares). Using high income crops such as tobacco, tomatoes, onions, peppers, etc., and obtaining two crops per year, the tractor could be used economically by a single medium-sized farmer.

Economic Analysis (see Appendix III):

Total fixed cost/year (Tractor and equipment) . . . . $1257.48 ----- I
Total variable cost/year (Tractor and equipment) . . 916.25 ----- II

Adding I and II
Total fixed and variable cost/year
(Tractor and equipment) . . . . $2183.81 ----- III
Total cost of inputs per year . . . . 5173.00 ----- IV

Adding III and IV
Total cost of production per year . . . . $7356.81 ----- V
Gross Income . . . . $11,250.00 ----- VI

Gross Income (VI)	$11,250.00
Total cost of production (V)	7,356.81
Net Income	$ 3,893.19/year

$324.43/month
$389.32/hectare/year

This would be a good income for an individual farmer and could be improved if the high income crops were grown.

The tractor is utilized more efficiently at 470 hours per year. This size tractor could be an alternative for privately owned medium-sized farms and possibly for small farmers using irrigation and growing two to three high income crops per year.

Alternatives for Using a Forty to Seventy Horsepower Tractor in Medium Sized Farms (Seven to Twenty-Two Hectares)

These tractors have been under used on these farms for some ten to fifteen years. They have been used only for tillage practices and transportation. The tractors and equipment could be used more efficiently in a multi-farm system.

An economic analysis needs to be done to see how many hectares an average tractor and associated equipment could work. (See Appendix IV.)

Tractor specifications:

PTO performance	52.54 horsepower
Drawbar performance	47.47 horsepower

Assumptions:

1. Assuming a maximum of 10 days for plowing operations.
2. The farmer will get 2 crops per year under irrigation.
3. Ten years life of the tractor (600 hrs/year).

Total fixed cost per year (Tractor and equipment) . . .	$4989.09 -----	I
Total variable cost per year (Tractor and equipment) .	3513.04 -----	II
Adding I and II		
Total fixed and variable cost/year (Tractor and equipment)	$ 8,502.13 -----	III
Total cost of inputs/year	28,390.18 -----	IV
Adding III and IV		
Total cost of production/year	$35,892.31 -----	V
Gross Income	$62,403.75 -----	VI

Gross Income (VI)	$62,403.75
Total Cost of Production (V)	36,892.31
Net Income	$25,511.44/year

$2125.95/month
$459.91/hectare/year

Farmers could realize the above income per year, using one of the lower income crops. The tractor and equipment could be used for different row crops such as beans, sorghum, cowpeas, etc.

Multi-Farm Machinery Use Systems for the Medium Size Farms

1) Pooling of individually owned machinery by informal and formal groups (tractor ownership by private groups).

2) Commercial enterprise operated part time by farmer contractors or full time machinery service contractors. (The custom tractor system.)

3) Hiring, renting or leasing schemes offered by machinery dealers or cooperatives.

Informal, neighborhood sharing and pooling of individually owned machinery by small groups of farmers in a restricted area is a common practice. The members of the group must be closely linked by family, friendship or locality. These schemes have generally been successful. In many such schemes, the basic power unit (tractor or other prime mover) is owned in common by the farmers in the group with other implements, special machines and equipment being owned by individual farmers in the group. For example, when maize production is common on all farms in the group, one farmer may own a planter, one a cultivator, another a field sprayer and another an ensilage cutter. The machinery is then used in turn by each farmer in the group and the need for each farmer to own all four machines or implements is eliminated.

William J. Chancellor (1978) explained in his work that in most Asian economies where tractors represent large capital items, some means for pooling the resources of several persons is usually necessary for the purchase of a tractor. In many cases, the grouping is only for concentrating funds, but sometimes a more extensive structure is involved among the participants. (He calls this scheme tractor ownership by a private group.) In Guatemala, it would be possible for several persons to pool their resources in order to buy a tractor, thus enabling each member of the group to buy an implement.

Farmer contractor. Machinery hire services are multi-farm use systems in which practicing farmers purchase machinery primarily for use on their own farms, but use any surplus capacity to provide machinery services to other farmers.

They usually operate in a limited radius and may be paid for their services in cash or in kind. Normally, contractual work will be done only when the machinery owner has completed his own operation. Thus, the amount of contract work he can undertake will depend on the amount of his own work.

The farmer contractor is an independent person who makes his own investment, sets his own operating conditions, negotiates his own charge rates, and succeeds or fails, in economic terms, on his own performance. This system can result in unfair exploitation of small farmers by farmer contractors. In most countries, however, the system has a good record of success from the viewpoint of both the contractor and the user.

William J. Chancellor (1978) calls this scheme the custom tractor system. Both larger four-wheel tractors (45 - 70 hp) and two-wheel tractors (8 - 11 hp) power tillers participated in tractor hire services in Thailand and Malaysia.

Another method of multi-farm use of machinery is the full time machinery hire service. Here the machinery is used full time on hire to someone other than the owner. This type of service is not restricted by the necessity of working on a specific farm unit first. Hence, the range of services offered is usually more comprehensive, mainly because working time and area covered needs to be optimized for economic viability. The full time contractor usually has to undertake non-seasonal and often off-the-farm work if he is to achieve full employment. This off-the-farm work may include land development, such as land leveling and irrigation/drainage work and off-farm transport of both farm and non-agricultural products. This system requires a high level of managerial skill in terms of investment, labor relations, customer relations and planning.

Another broad category of multi-farm machinery use that could be introduced to the medium sized farms is the machinery hiring, renting or leasing scheme. The main difference between this scheme and all the other categories of systems is that the machinery, often including the primary mover, is provided without operator, and maintenance and repairs are the responsibility of the users. The system can be offered by machinery dealers or cooperatives and can be linked with sales of related inputs of service. This scheme is being used in the southern region of Guatemala and is being offered to individual farmers involved in large scale farming operations.

The weakness of the system is that operator and maintenance standards for use may be low and are nearly always highly varied, which tends to reduce the normal economic life of the machinery. As a result, use of services can be relatively costly.

The advantages are:

1) The supplies may be able to increase his sales of related products and he may be able to purchase more machinery, thereby becoming eligible for volume discounts.

2) The user does not have to borrow or tie up his own investment and has control of when and how the machinery will be used.

3) The system, properly operated, can give good results in making mechanical power technology available to the medium sized farmers.

PROBLEMS WITH THE INTRODUCTION OF MECHANIZATION

Some of the many problems that restrict the introduction of mechanization in Guatemala are:

1) The lack of an appropriate government body which is adequately staffed and financed, and which has the capability, prestige and authority to guide the planning and execution of the introduction, support and use of mechanization.

2) A nonexistence of a mechanization program which is structurally and functionally able to generate the information necessary for making decisions and mechanization inputs into the development process, and which is properly integrated with other rural development research activities.

3) Lack of an adequate short and long term training and education program to develop the manpower required for mechanization.

4) Lack of an extension structure and approach which recognizes the role of mechanization in the agricultural production process and provides the needed guidance for mechanization introduction and use.

5) Total provision of mechanization inputs is from developed countries.

A report from Unido (1979) shows a division of the developing countries into four categories based on the way local requirements for agricultural tractors and allied equipment are met. Guatemala was shown as being in Category A, which is defined as those countries which fully import assembled units.

Mechanization Foreign Aid Programs

Foreign aid programs have been limited in their consideration of all the alternative sources of machinery by policies of the donor agency (aid in kind, rather than cash or credits, and tied loans requiring the purchase of machinery from the donor country). Other foreign aid donors, particularly multilateral financing institutions, require that machinery be obtained through international tenders. Such a policy very often means that the machinery which is really appropriate cannot be obtained and compromise selections are made at the expense of efficiency and effectiveness.

Problems Caused by the Introduction of Mechanization

The principal problem caused by the introduction of mechanization could be the displacement of hand labor in highly populated areas. There are different viewpoints on this subject. Coolman (1981) states that in densely populated areas, one often has to find other job opportunities for the displaced laborers. In those areas where labor peaks in threshing season, the restriction factor exists because of the total amount of rice planted. The use of a single thresher can lead to a bigger area put under irrigation and the total production of rice is increased.

CONCLUSIONS AND RECOMMENDATIONS

1. The small farms are the ones that need more government assistance. They are less developed in every sense and they hold a very high percentage of Guatemala's rural poor people.

As seen in Table 4, the small farms, representing about ninety percent of the total farms, have only sixteen percent of the land, and the larger farms, representing about ten percent of the total farms, have eighty-four percent of the land. Therefore, agrarian reform with redistribution of the land would help a majority of these people.

a. Considering the actual status of these farms and to avoid problems with displacement of hand labor on the farms, the introduction of improved hand tools, animal power, and improved draft animal equipment needs to be considered since this has been the appropriate mechanization technology until now. Minimum tillage needs to be used as much as possible in order to avoid soil losses caused by erosion.

b. In the future, as rural wages increase and manpower becomes scarce on these farms due to better job opportunities in industry, the introduction of the small tractor in a government sponsored multi-farm system appears to be the best alternative. However, consideration must be given to the steep slope of the land while the small tractor is being introduced.

2. Medium sized farms are more developed than the small sized farms. Irrigation is used and at least two crops per year are produced. Here, the manpower is scarce and when found, higher wages must be paid.

The appropriate technology for these farms could be:

a. The introduction of a small tractor (ten to twenty horsepower) to a single farm, accompanied by adequate technology for the irrigated area.

b. The efficient use of the forty to seventy horsepower tractor which has been introduced in the past needs to be continued. As explained before, the tractors need to be used in a multi-farm use system in order to be used economically and efficiently.

3. Special studies need to be done in each region to test and evaluate the tools, equipment, and tractors recommended in this report in order to evaluate their performance.

4. In both small and medium sized farms, mechanization should be complemented with the use of new, high productive varieties of seeds, adequate application of fertilizer and pesticides, adequate irrigation where possible, and other practices in order to achieve the goal of increased yield per unit area.

5. The improved hand and animal tools should be manufactured by village blacksmiths in small shops.

For more complicated equipment and tractor manufacture, the country could engage in joint ventures with foreign manufacturers for local assembly/manufacturing. The foreign firms could provide a full line of machinery from which appropriate types and sizes could be selected for local requirements.

6. Promotion of international and regional mechanization organizations that would cooperate among themselves in an exchange of information, prototypes, etc., would be helpful.

7. In order to insure that mechanization development is part of the plan, programs and projects should be prepared as supporting components to agricultural development programs, and that the mechanization strategy is included in the agricultural sector plan. The mechanization planning unit should be included as part of the existing Bureau of the Ministry of Agriculture.

The planning unit should be responsible for the preparation of mechanization development strategies, programs, and projects and insuring their implementation. The planning unit should also advise on policies which affect mechanization development. To carry out the actual planning process, the unit should have a planning team with multi-disciplinary expertise.

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APPENDIX I

Economic Analysis of an Agro-Util Tractor for Use on a Single Small Farm

Total Estimated Cost to Operate an Agro-Util Tractor:

Tractor and equipment initial cost:

Tractor (diesel)		$4990.00
Equipment		
2-10" bottom plow	$390.00	
Disc--52" width of cut	266.00	
Planter	225.00	
Cultivator	117.00	
Total Implements		998.00
Tractor and Implements		$5988.00

Performance (estimated information) Using 82.5% as Average Field Efficiency:

1. Plow: 2-10" bottom — Speed -- 2.27 mph
   Width -- 18" = 0.4572 meters — 3.64 km/hour

   $$\text{Capacity, ha/hr} = \frac{SWE}{10}$$

   S = speed (km/hr)
   W = width of the implement (meters
   E = efficiency (average 82.5%)
   10 = a constant

   $$\text{Capacity ha/hr} = \frac{3.64 \text{ km/hr} \times 0.4572 \text{ m} \times 0.825}{10} = 0.137 \text{ ha/hr}$$

   Hours per day = 10; Then 0.137 ha/hr x 10 hrs/day = 1.37 ha/hr

   Fuel 0.9 gal/hr -- gasoline -- constant to change to diesel is 0.9 gal/hr x 0.71 = 0.64 gal/hr diesel

2. Disc Harrow: 52" (tandem)
   Width 52" = 1.32 meters — Speed 2.5 mph = 4 km/hr

   $$\text{Capacity ha/hr} = \frac{4 \text{ km/hr} \times 1.32 \text{ meters} \times 0.825}{10} = 0.4356 \text{ ha/hr}$$

   $$= 4.36 \text{ ha/day}$$

   Fuel 0.85 gal/hr x 0.71 = 0.60 gal/hr diesel

3. <u>Cultivating</u>: 1 row = 30" = 0.762 meters
   Speed 3 mph = 4.8 km/hr

   Capacity ha/hr = $\frac{4.8 \text{ km/hr} \times 0.762 \text{ m} \times 0.825}{10}$ = 0.30 ha/hr = 3 ha/day

   Assume fuel 1/2 of plowing = 0.32 gal/hr

4. <u>Planting same as Cultivating</u>

   1 row = 30" Speed 3 mph Capacity = 3 ha/day
   Fuel 0.32 gal/hr

Fuel Consumption Considering the Top Small Farm
Size as a Unit, 7 ha.:

Plowing:
$\frac{7 \text{ ha}}{1.37 \text{ ha/day}}$ = 5.11 day x 10 hrs/day = 51.09 hrs x 0.64 gal/hr
= 32.7 gal x $1.19/gal = $38.91

Disking:
$\frac{7 \text{ ha}}{4.36 \text{ ha/day}}$ = 1.60 days x 10 hr/day x 2 = 32.11 hrs x 0.60 gal/hr
= 14.27 gal x $1.19/gal = $22.93

Cultivating:
$\frac{7 \text{ ha}}{3 \text{ ha/day}}$ = 2.33 days x 10 hr/day x 2 = 46.67 hrs x 0.32 gal/hr
= 14.93 gal x $1.19/gal = $17.77

Planting:
$\frac{7 \text{ ha}}{3 \text{ ha/day}}$ = 2.33 days x 10 hrs/day = 23.33 hrs x 0.32 gal/hr
= 7.47 gal x $1.19/gal = $ 8.88

Total Number of Hours/Year = 153.20

Total Cost of Fuel/Year = $88.49

Estimated Cost Analysis Assuming an 8-year Life
of the Tractor--3200 hrs (400 hrs/year) (Assume
Tractor Used for Other Purposes such as Transportation):

<u>Fixed Costs</u>:	Depreciation (12.5% per year)	
	Tractor	$623.75
	Implements	124.75
	Interest on investment (12%)	359.28
	Taxes)	
	Insurance) 2.5%/year	149.70
	Housing)	
	Total fixed costs/year	$1257.48 --------- I

Variable Costs:

Fuel	$ 88.49	
Lubrication and daily service (15% of fuel cost)	13.27	
Repair and maintenance (6.25% of initial cost/year)	374.25	
Labor ($0.50/hr x 153.20 hrs)	76.60	
Total variable costs/year	$552.62	--------- II

Adding I and II
Fixed and Variable Costs (tractor and equipment) = $1810.09 - III

Information regarding crops:
Half of the area will be planted with maize and half with beans.

INPUT

Seed

Maize -- 40 lbs/ha x $0.42/lb = $16.80/ha x 3.5 ha =	$ 50.80
Beans -- 100 lbs/ha x $0.52/lb = $52.00/ha x 3.5 ha =	182.00
Total cost of seed	$240.00

Fertilizer

Maize -- 1000 lbs/ha x $0.15/lb = $140.00/ha x 3.5 ha =	$490.00
Beans -- 1000 lbs/ha x $0.14/lb = $140.00/ha x 3.5 ha =	490.00
Total fertilizer cost	$980.00

Harvesting (by hand)

Maize -- 4 man/day/ha x $2.50/day x 3.5 ha =	$ 35.00
Beans -- 10 man/day/ha x $2.50/day x 3.5 ha =	87.50
Total cost of harvesting	$122.50

Threshing (by hand)

Maize -- $0.25/100 lbs x 14,000 lbs =	$ 35.00
Beans -- $0.50/100 lbs x 7,000 lbs =	35.00
Total threshing cost	$70.00

Total inputs -- $240.00 + 980.00 + 122.50 + 70.00 = $1412.50 -- IV

Adding III and IV
Total cost of production = $1810.09 + 14.12.50 = $3222.59 -- V

OUTPUT

Crop	Expected Yield	Selling Price	
Maize	-- 4000 lbs/ha x 3.5 ha =	14,000 lbs x $0.10/lb =	$1400.00
Beans	-- 2000 lbs/ha x 3.5 ha =	7,000 lbs x $0.25/lb =	1750.00
Gross Income			$3150.00 -- VI

Gross Income (VI)	$3150.00
Cost of Production (V)	3222.59
Net Income	$ -72.59 per year

APPENDIX II

Economic Analysis of an Agro-Util Tractor in a
Multi-Farm use of Power System for the Small Farms

Assumptions:

- -- The tractor characteristics and equipment are the same as in Appendix I.
- -- A maximum of fifteen days at 10 hrs per day is available for the plowing operation.

Total Capacity of Tractor:
Performance 1.37 ha/day.
1.37 ha/day x 15 days x 10 hrs/day = 20.55 ha.

Fuel Consumption and Total Hours
of Work Per Year:

1. Plowing:
   15 days x 10 hrs/day = 150 hrs x 0.64 gal/hr = 96 gal x $1.19/gal
   = $114.24

2. Disking:
   $\frac{20.55 \text{ ha}}{4.36 \text{ hrs/day}}$ = 4.71 days x 10 hrs/day x 2 = 94 hrs x 0.60 gal/hr
   = 56.56 gal x $1.19/gal = $67.30

3. Cultivating:
   $\frac{20.55 \text{ ha}}{3.0 \text{ hrs/day}}$ = 6.85 days x 10 hrs/day x 2 = 137 hrs x 0.32 gal/hr
   = 43.84 gal x $1.19/gal = $52.17

4. Planting:
   $\frac{20.55 \text{ ha}}{3.0 \text{ hrs/day}}$ = 6.85 days x 10 hrs/day = 68.5 hrs x 0.32 gal/hr
   = 21.92 gal x $1.19/gal = $26.08

   Total hrs/year 449.5 hrs.
   Total fuel/year $259.79

Fixed Costs: Same as for 7 ha . . . . $1257.48 --- I

Variable Costs:

Fuel	$259.79	
Lubrication and daily service	38.92	
Repair and maintenance	374.25	
Labor ($0.50/hr x 449.5 hrs)	224.75	
Total variable costs/year		$ 897.76 --- II

Adding I and II
Total fixed and variable costs of tractor and equipment $2155.24 ---III

Information regarding crops:

INPUTS

Cost of Seed/ha

Maize -- $16.80/ha x 10.25 ha =	$ 172.62	
Beans -- $52.00/ha x 10.28 ha =	534.30	

Fertilizer

Maize -- 1000/lbs/ha x $0.14/lbs x 10.28 ha =	$1438.50	
Beans -- 1000/lbs/ha x $0.14/lbs x 10.28 ha =	1438.50	

Harvesting (by hand)

Maize -- 4 man/day/ha x 10.28 ha x $2.50/day =	$ 102.80	
Beans -- 10 man/day/ha x 10.28 ha x $2.50/day =	257.00	

Threshing (by hand)

Maize -- $0.25/100 lbs x 41,100 lbs =	$ 102.75	
Beans -- $0.50/100 lbs x 20,500 lbs =	102.75	
Total Inputs		$4,149.22 -- IV

Adding III and IV
Total production cost: $2155.24 + $4149.22 = $6,304.46 -- V

OUTPUTS

Crop	Expected Yield	Selling Price	
Maize	-- 4000 lbs/ha x 10.28 ha x $0.10/lb =	$4110.00	
Beans	-- 2000 lbs/ha x 10.28 ha x $0.25/lb =	5140.00	
Gross Income			$9,250.00 -- IV

Gross Income (IV)	$9250.00
Cost of Production (V)	6304.46
Net Income	$2945.54/year

$245.46/month
$143.34/ha/year

APPENDIX III

Economic Analysis of an Agro-Util Tractor for Using on a Single, Medium Farm

Assumptions:

-- In the seven to twenty-two hectare range, a ten hectares farm was chosen for the analysis.

-- Two crops per year are obtained under irrigation.

Tractor and Equipment Initial Cost:

Tractor (diesel)		$4990.00
Equipment		
2-10" bottom plow	$390.00	
Disc--52" width of cut	266.00	
Planter	225.00	
Cultivator	117.00	
Ridger/Furrower	48.00	
Implements (total cost)		1046.00
Tractor and Implements (total cost)		$6036.00

Fixed Costs:

Depreciation 12.5%		
Tractor	$623.75	
Implements	130.75	
Interest 12%	362.16	
Taxes)		
Insurance) 2.5%	150.90	
Housing)		
Total Fixed Costs		$1267.56 -- I

Fuel Consumption for Different Operations on Ten Hectare Farm:

Plowing:

$\frac{10 \text{ ha}}{1.37 \text{ ha/day}}$ = 7.25 x 10 hrs/day = 72.99 hrs x 2 = 145 hrs x 0.64 gal/hr

= 93.43 gal x $1.19/gal = $111.18

Disking:

$\frac{10 \text{ ha}}{5.28 \text{ ha/day}}$ = 2.29 days x 10 hrs/day x 2 = 45.87 hrs x 2 = 91.74 hrs

x 0.60 gal/hr = 55.04 gal x $1.19/gal = $65.50

Cultivating:

$\frac{10}{3 \text{ ha/day}}$ = 3.33 days x 10 hrs/day x 2 = 66.67 hrs x 0.32 gal/hr

= 21.33 gal x $1.19/gal = $25.39

Planting:

$\frac{10\ ha}{3.66\ ha/day}$ = 3.33 days x 10 hrs/day x 2 = 66.67 hrs x 0.32 gal/hr

= 21.33 gal x $1.19/gal = $25.39

Ridging:

$\frac{10}{2\ ha/day}$ = 6.15 days x 10 hrs/day x 2 = 100 hrs x 0.31 gal/hr

= 31 gal x $1.19/gal = $36.98

Total number of hours per year = 470
Total Fuel costs per year $264.35

Variable Costs:

Fuel	$264.35
Lubricants and daily service (15% of fuel cost)	39.65
Repair and maintenance	327.25
Labor ($0.50/hr x 470 hrs)	235.00

Total Variable Costs (tractor and equipment) $ 916.25 -- II

Adding I and II
Total fixed and variable costs for tractor and equipment $2183.81 --III

Information Regarding Crops:

INPUTS

Cost of Seed/ha

Maize -- $16.80/ha x 10 ha =	$ 160.00
Beans -- $52.00/ha x 10 ha =	520.00

Fertilizer

Maize -- 1200 lbs/ha x 10 ha x $0.14/lb =	$1680.00
Beans -- 1200 lbs/ha x 10 ha x $0.14/lb =	1680.00

Harvesting

Maize -- 4 man days/ha x 10 ha x $2.50/day =	$ 100.00
Beans -- 10 man days/ha x 10 ha x $2.50/day =	250.00

Threshing

Maize -- $0.25/100 lbs x 50,000 lbs =	$ 125.00
Beans -- $0.50/100 lbs x 30,000 lbs =	150.00

Irrigation

Cost of irrigation $25/ha x 20 ha =	$ 500.00

Total Inputs $5173.00 -- IV

Adding III and IV
Total Production Costs: $2183.81 + 5173.00 = $7356.81 -- V

OUTPUT

Crop	Expected Yield	Selling Price	
Maize --	5000 lbs/ha x 10 ha x	$0.10/lb =	$5000.00
Beans --	2500 lbs/ha x 10 ha x	$0.25/lb =	6250.00

Gross Income $11,250.00 -- VI

Gross Income (VI)	$11,250.00
Production Costs (VI)	7,356.81
Net Income	$ 3,893.19/year

$324.43/month
$389.32 ha/year

APPENDIX IV

Economic Analysis of a 47.47 hp Tractor in a Multi-Farm Use of Power Systems for Medium Farms

Tractor Specifications:
-- pTO performance 52.54 horsepower
-- Drawbar performance 47.47 horsepower

Equipment for Corn Production (April 1981 figures):

Diesel tractor	$15,490.00
Plow 3-14" bottoms	1,850.00
Tandem disc -- 10 feet --complete with remote hydraulic cylinder and tires	3,689.00
Planter -- 4 rows --four units mounted on tool bar with fertilizer and pesticide applicator	3,800.00
Cultivator -- 4 rows (30" spacing)	1,685.00
Approximate total cost	$26,514.00

There is a two-row (30" spacing) pull type corn picker with husking rolls that could be included, but it is very expensive ($14,000.00) and is not considered economically feasible for Guatelama's conditions.

Performance:
The speeds are assumed for each operation.
--Maximum horsepower 47.47; speed 5.07 miles per hour

Plowing: 3-14" bottom plow = 1.07 meters; speed 4 mph = 6.4 km/ha

Capacity, ha/hr = $\frac{SWE}{10}$, where:

S = speed (km/hr)
W = width of the implements (meters)
E = Efficiency (Hunt, Donnell, 1979)
10 = constant

$$\text{Capacity ha/hr} = \frac{1.07 \text{ m} \times 6.4 \text{ km/hr}}{10} \times .81 = 0.55 \frac{\text{ha}}{\text{hr}} \times \frac{10 \text{ hrs}}{\text{day}} = 5.54 \frac{\text{ha}}{\text{day}}$$

If there are ten days to plow, the total capacity of the tractor would be:
10 days x 5.54 ha/day = 55.47 ha

Total Hours for Each Operation:

1. Plowing:

$$\frac{55.47 \text{ ha}}{5.54 \text{ ha/day}} = 10 \text{ days} \times 10 \text{ hrs/day} \times 2 = 200 \text{ hours}$$

2. Disking: 10 ft = 3 meters; speed 4 mph = 6.4 km/hr

$$\text{Capacity ha/day} = \frac{3\text{m} \times 6.4 \text{ km/hr} \times 0.835}{10} = 1.60 \frac{\text{ha}}{\text{hr}} = 16.03 \text{ ha/day}$$

$$\frac{55.47 \text{ ha}}{16.04 \text{ ha/day}} = 3.46 \text{ days} \times 10 \text{ hrs/day} \times 4 = 138.39 \text{ hours}$$

3. Planting: 4 rows, 30" = 3.05 meters; speed 3 mph = 4.8 km/hr

$$\text{Capacity ha/hr} = \frac{3.05\text{m} \times 4.8 \text{ km/hr} \times 0.69}{10} = 1.01 \frac{\text{ha}}{\text{hr}} \times 10 \text{ hrs} = 10.10 \frac{\text{ha}}{\text{day}}$$

$$\frac{55.47 \text{ ha}}{10.10 \text{ ha/day}} = 5.49 \text{ days} \times 10 \text{ hrs/day} \times 2 = 109.82 \text{ hours}$$

4. Cultivating: 4 row cultivator, 30" = 3.05m; speed 4 mph = 4.6 km/hr

$$\text{Capacity ha/hr} = \frac{3.05 \times 6.4 \text{ km/hr} \times 0.79}{10} = 1.54 \frac{\text{ha}}{\text{hr}} = 15.42 \text{ ha/day}$$

$$\frac{55.47 \text{ ha}}{15.42 \text{ ha/day}} = 3.59 \text{ days} \times 10 \text{ hrs/day} \times 4 = 143.88 \text{ hours}$$

Total Hours per year = 592.09

Fuel Consumption: (Schlender, John R. and Schrock, Mark O.)

1. Plow 8" deep
1.68 gal/acre = 4.15 gal/ha x 55.47 ha x 2 = 460 gal x $1.19/gal

= $547.88

2. Tandem disc
0.55 gal/acre = 1.35 gal/ha x 55.47 ha x 4 = 299.53 gal x $1.19/gal

= $356.45

3. Cultivating
0.45 gal/acre = 1.11 gal/ha x 55.47 ha x 4 = 246.29 gal x $1.19/gal

= $293.08

4. Planting
   0.50 gal/acre = 1.235 gal/ha x 55.47 ha x 2 = 137.01 gal x $1.19/gal

   = $163.04

   Total Cost for Fuel Consumption per Year $1360.45

Repair and Maintenance: (Schlender, John R. and Schrock, Mark O.)

Tractor: $\frac{0.10/hr}{1000 \text{ (initial cost)}} = \frac{0.10 \times 15490}{1000} \times 592.09 = \$\ 917.15$

Equipment: $\frac{0.48/hr}{1000 \text{ of initial cost}}$

1.	Plow: $\frac{0.48 \times \$1850}{1000} \times 200$ hrs =	$ 177.60
2.	Tandem disc: $\frac{0.48 \times \$3689}{1000} \times 138.39$ =	$ 245.05
3.	Planter: $\frac{0.48 \times \$3000}{1000} \times 109.82$ =	$ 200.31
4.	Cultivator: $\frac{0.48 \times \$1680}{1000} \times 143.88$ =	$ 116.37
	Total Repair and Maintenance Cost	$1656.48

Fixed Costs:
--Assuming the life of the tractor and equipment to be 10 years

Depreciation

Tractor (10% of initial cost)		$1549.00
Equipment (10% of initial cost)		1102.40
Interest on Investment (12%)		1674.84
Taxes)		
Insurance)	2.5%	662.85
Housing)		

Total Fixed Costs (tractor and equipment) $4989.09 -- I

Variable Costs:

Fuel	$1360.45
Lubrication	204.07
Repair and Maintenance	1656.48
Labor ($0.50/hour x 592.09 hrs)	292.04

Total Variable Costs (tractor and equipment) $3513.04 -- II

Adding I and II
Total Variable and Fixed Costs for tractor and equipment $8502.13 -- III

Information Regarding Crops:

INPUTS

Cost of Seed/ha

Maize -- $16.80/ha x 55.47 ha =	$ 931.90
Beans -- $52.00/ha x 55.47 ha =	2884.44

Fertilizer

Maize -- 1200 lbs/ha x $0.14/lbs x 55.47 ha =	$9318.96
Beans -- 1200 lbs/ha x $0.14/lbs x 55.47 ha =	9318.96

Cost of Irrigation

$25/ha x 110.94 ha =	$2773.50

Harvesting by Hand

Maize -- 4 man day/ha x 55.47 ha x $2.50 day =	$ 554.70
Beans -- 10 man day/ha x 55.47 ha x $2.50/day =	1386.75

Threshing

Maize (by threshing machine contractor service) -- $0.15/100 lbs x 277,350 lbs =	$ 416.02
Beans (by threshing machine contractor service) -- $0.30/100 lbs x 139,425 lbs =	418.28

Total Inputs $28,390.18 -- IV

Adding III and IV
Total Cost of Production $36,892.31 -- V

OUTPUT

Crop	Expected Yield	Selling Price
Maize --	5000 lbs/ha x 55.47 x $0.10/lb =	$27,735.00
Beans --	2500 lbs/ha x 55.47 x $0.25/lb =	34,668.75

Gross Income $62,403.75 -- VI

Gross Income (VI)	$62,403.75
Production Cost (V)	36,892.31
Net Income	$25,511.44

$2125.95/month
$459.91/ha/year

MECHANIZATION ALTERNATIVES FOR THE MOST COMMON SIZES OF FARMS IN GUATEMALA

by

VICTOR HUGO MENDEZ E.

B.Sc., Universidad de San Carlos de Guatemala
Guatemala 1979

AN ABSTRACT OF A MASTER'S REPORT

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requirements for the degree

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Department of Agricultural Engineering

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Manhattan, Kansas

1982

ABSTRACT

This report deals specifically with the agricultural situation and the mechanization status in a developing country, Guatemala. It aims at an approach toward determining the mechanization alternatives for the most common sizes of farms; namely, the small (less than seven hectares) and the medium (seven to twenty-two and one-half hectares) sized farms.

Some ideas are presented about how to increase food production on the small- and medium-sized farms by means of modernization of the whole agricultural system.

A general idea is given for introduction of improved hand tools and improved animal equipment as the appropriate technology for the small farms at the present time.

A small four-wheel tractor and associated equipment for a production system is presented and an economic analysis was done with different situations. This tractor could possibly be used in the future on the small farms, or at the present time on the medium-sized farms.

An economic analysis is presented for a fifty horsepower tractor and associated equipment because, on the average, it is the most commonly used tractor on the medium-sized farms. The analysis indicates that this size tractor with appropriate equipment could be used in a multi-farm system.

Finally, different schemes for using tractors in a multi-farm use system are discussed, as well as some problems associated with the introduction of mechanization.