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TRACTORS AND THEIR USE IN AGRICULTURE IN THE DEVELOPING AREAS OF THE WORLD [1]

by

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1/ The views and opinions expressed in this paper are those of the consultant and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

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INTRODUCTION AND SUMMARY

It has been said that "Nothing is quite so powerful as an idea whose time has arrived." The writer senses that in the developing nations of the world, the idea of mechanical power to supplement and replace human power in the battle of supplying food for their growing population is on the verge of arriving. Those working in the area of power and equipment will agree that it is not difficult to generate a demand for tractors in developing nations.

This conference portends the growing concern for tractor power and the management associated with providing and using it. There seems to be a growing awareness of the importance of placing at the disposal of farmers the amount and kind of power so that food can be produced efficiently and in sufficient quantities; and that the dependence solely on humans for the productive power of agriculture inhibits the adequate growth in the countries' standard of living and industrialization, among other things. In sum, the lack of an appropriate increase in mechanical power will likely increase further the gap between the "have" and the "have not" nations.

This report will attempt to define the importance, status and problems of tractor power associated with increasing yields in the developing countries, estimate the minimum amount of power needed and appropriate time schedules in connection therewith, estimate the capital costs for plants to manufacture the tractors needed, partially identify the types and sizes of tractors needed, make a case for more comprehensive evaluations, including cost/benefit analyses of the power equipment combinations, and define and point up the need for comprehensive service to accompany an expansion of tractors.

Noteworthy points are:

--- that there is a positive relationship of horsepower input per unit area to yields of agricultural products per unit of area;

--- that the aforementioned relationship offers a more scientific means of planning and implementing the mechanical power requirements of a country than any instrument heretofore;

--- that the tractor and associated equipment are dependent on each other. We must not think solely in terms of tractors. Low hours of tractor use is partially the result of too little or no tractor powered equipment;

--- that the development of exotic or unconventional tractor designs for the developing nations is not justified at this time. Rather, resources should be directed to supply the types and size, with modern accessories, that have proven out elsewhere. The row-crop type is preferred;

--- that a range of tractor sizes and types are needed to satisfy the varying agricultural situations in a particular country;

--- that the results of a cost/benefit analysis is an important criteria in the farmer's selection of power and associated equipment;

--- that comprehensive service should be provided, farmer orientated, and managed by modern practices and techniques. These services include credit to both the farmer and service agency, and competitive demonstrations that are carried through to the final yield stage;

--- that direct subsidies on tractors and equipment may be a hindrance to progress;

--- that maximum progress in advancing mechanization can be made through individuals and concerns in real competition and with a profit motive. Government agencies' role is in providing credit, conducting demonstrations and teaching the <u>what</u>, <u>why</u> and <u>how</u> of tractor and equipment operation.

IMPORTANCE, STATUS AND PROBLEMS

Power, the Focal Point of the Farming System

A farming operational system, including the type of equipment, must be planned around a power source. The following sources and combinations are available for this purpose in the developing nations:

1. Human
2. Human + Animal
3. Human + Animal + Mechanical
4. Human + Mechanical.

The above power sequence indicates the progression of agriculture from a low standard of living, labor productivity, and energy input per unit area to a higher. The relative proportion of human energy input in Number 1 is greatest and decreases to a minimum in Number 4. The next step beyond Number 4 is automation, but this should not concern us at this time because of the low power plateau which presently characterizes most, if not all, of the developing nations.

The developing countries are utilizing all four of these power sources in varying proportions, depending upon the pecularities of their situation and environment.

Power is an essential input, along with equipment, fertilizer, seed, pesticides and water, for modernizing agriculture. Since the problem of the developing countries is one of increasing the production of food, the power should be of the amount and kind that will contribute to increased yields as a top priority.

Power makes its contribution to increased production through timely and effective operations; for example, a better seedbed prepared quickly to take advantage of the optimum time to seed and to increase residual moisture, or to make it possible to follow with a second or third crop; uniform and timely distribution of chemicals to get pest control; mechanical harvesting and threshing to save the estimated 10 to 15 percent or more of the grains now being lost.

Multi-cropping to increase the production per acre per year is only possible when the seedbed preparation and harvesting operations can be carried out quickly and timely. This requires additional power.

There is another way, although indirect, by which tractors contribute to increased food production--increasing the size of the fields and consequently the net amount of land under production. Table I serves to indicate the amount of farming land lost to production for different sizes of fields by the bunds separating the fields. This table assumes square fields with a three-foot wide bund separating each side from an adjacent field. It may be noted that with one-acre fields, nearly three percent is lost from production; with one-half acre fields, eight percent.

The average size of fields in the developing nations is not reliably available,but it is known to be very small--much less than one acre and perhaps around one-half acre. If this be true, an eight-percent increase in farming land means an increase in the food grain output of eight percent. Further support to the argument of reducing wasteland through large fields is the fact that these fields represent the better farming land of the country.

TABLE I

Loss in Farming Land vs. Size of Fields*

Size of Field in Acres	Loss in Acres	Percentage
.5	.043	8
1	.029	3
2	.021	1
4	.014	.3
8	.01	.1
16	.007	.04
32	.005	.01

*Assumes fields are square and inter-connected on all four sides with three-feet wide bunds.

Tractor power makes it possible to combine small fields and level them for efficient, wasteless operational units. If the average size of field could be increased to eight acres, the loss would be negligible, about one-tenth of one percent, as indicated in Table I.

It should be mentioned in passing that the combining of fields to minimize the loss of farming land to borders, will permit the use of large land levelers and planes. As a nation raises its standard of living, so, too, will the cost of hand labor rise, and, of course, its reluctance to do the undesirable and unexciting jobs, regardless of the amount of pay. Eventually, it will become impossible to get labor to level satisfactorily by hand. The tractor and equipment then come into play as the only alternative. It is wise to plan for its efficient use now. In the author's opinion, a tractor-powered land plane does a far superior job in the matter of achieving proper smoothness and grade for successful flood type of irrigation than is possible with the conventional animal-pulled wooden plank. There are two basic requirements to do a satisfactory job of leveling and planing land: (1) a machine with a long wheel base (more than 20 feet) and (2) a blade that carries a generous amount of soil. Neither of these requirements are possible on a practical basis using animal power.

Improved and additional power contributes to a reduction of labor, elimination of peak labor loads and to convenience. Mechanical power is a catalyst for changing the attitudes and uplifting the social status and dignity of those who labor in agriculture. Farmers in 1969, enlightened through the advancing communications media, are more aware of the above values; consequently, they are restless, and eager to change to these beneficial values. Farmers who have at their command mechanical power tend to raise their sights to new horizons and regard their agricultural profession as more exciting and dynamic.

Lastly, mechanical power provides an open end for designing and using a whole new array of modern implements--implements that perform their functions better and faster for increased yields and production.

This section would not be complete without noting that mechanical power does not consume food sources of energy as do work animals. According to Johnson (8), "Power (mechanical) and equipment are the products of non-food energy and they are converters of non-food energy in performing the agricultural operations normally performed by men and animals. It is appropriate, then, to consider mechanization as a means of substituting non-food energy for food energy in order to make additional food available for the growing urban population."

Assessment of Available Horsepower

An assessment of the existing horsepower available for agricultural field production in various countries, regions and continents by kinds of power was made by the author for a study of "The World Food Problem."[1] The results are presented in Table II. The description of the procedure and limitations that follow in brief were taken largely verbatim from that report. The inclusion of the latter seems advisable to give the reader the background feel for the data presented herein without the necessity of referring to the original publication.

Stationary power units for irrigation and other uses are not included in the power analysis. The intention here is to assess approximately the horsepower now available for field work. But, it is recognized that a refined and complete study should include all power units that contribute to increased production.

The data for making the power calculations are generally for the year 1964 and are taken from the 1965 Production Yearbook by FAO.[2] In some instances, however, adjustments have been made on the basis of more recent information supplied by experts. For example, the 2,183,000 garden tractors reported for Japan were actually for 1963. According to A. D. Faunce of FAO, the number is increasing at the rate of 350,000 per year; so, a value of 2,500,000 was taken for 1964.

Arable land and land under permanent crops were taken as representing the agricultural area. This includes land for temporary fallow, temporary meadows for mowing or pasture, fruit trees, vines, shrubs and rubber plantations as well as crops. It is reasoned that all of the afore consume varying

TABLE II

Available H.P. per Hectare of Arable Land and Land under Permanent Crops[a]

	Africa	Asia	India	Ludh-Iana, Dist. India	West Paki-stan	Thai-land	Latin America	Taiwan	Oceania	U.A.R.	Israel	Europe	U.S.A.	U.K.	Japan	World
Tractor[b]	.03	.02	.008	.155	.025	.128	.18	.080	.33	.181	.815	.81	1.0	1.57	.004	.266
Garden Tractor[c]	-	.03	-	-	-	-	-	.063	.006	-	.007	.02	.014	.03	2.06	.024
Animal	.01	.10	.145	.059	.150	.099	.07	.063	.011	.065	.010	.08	-	.02	.088	.044
Human	.01	.05	.056	.027	.032	.091	.02	.113	.001	.12	.016	.02	.002	.09	.148	.024
Total	.05	.20	.21	.24	.207	.32	.27	.27	.35	.37	.85	.93	1.02	1.71	2.30	.36

[a]Calculations based largely on values taken from F.A.O.'s 1965 Production Yearbook(2)

[b]Defined by F.A.O. as wheel and crawler tractors developing over 8 H.P. and used in agriculture.

[c]Defined by F.A.O. as tractors developing under 8 H.P. and/or weighing under 850 kgs and used in agriculture

degrees of power. And, therefore, arable land and land under permanent crops should be used to calculate the power per unit area. Further, FAO states that Asia, Africa and South America frequently report only the area under major crops even though land under the broader classification was requested.

An estimate of the persons actually engaged in performing field and related work was not available. Therefore, FAO's figures on the number of both sexes engaged in agricultural operations was used. These figures include al economically active persons engaged principally in agriculture, forestry and fishing. Obviously, this will not be very accurate but it is the closest meaningful figure available.

The proportion of people engaged in agricultural operations in Europe is unusually high, causing skepticism about the validity of this figure. However, since Europe uses large amounts of mechanical power, the contribution of human power to the total, even though inflated, would be insignificant.

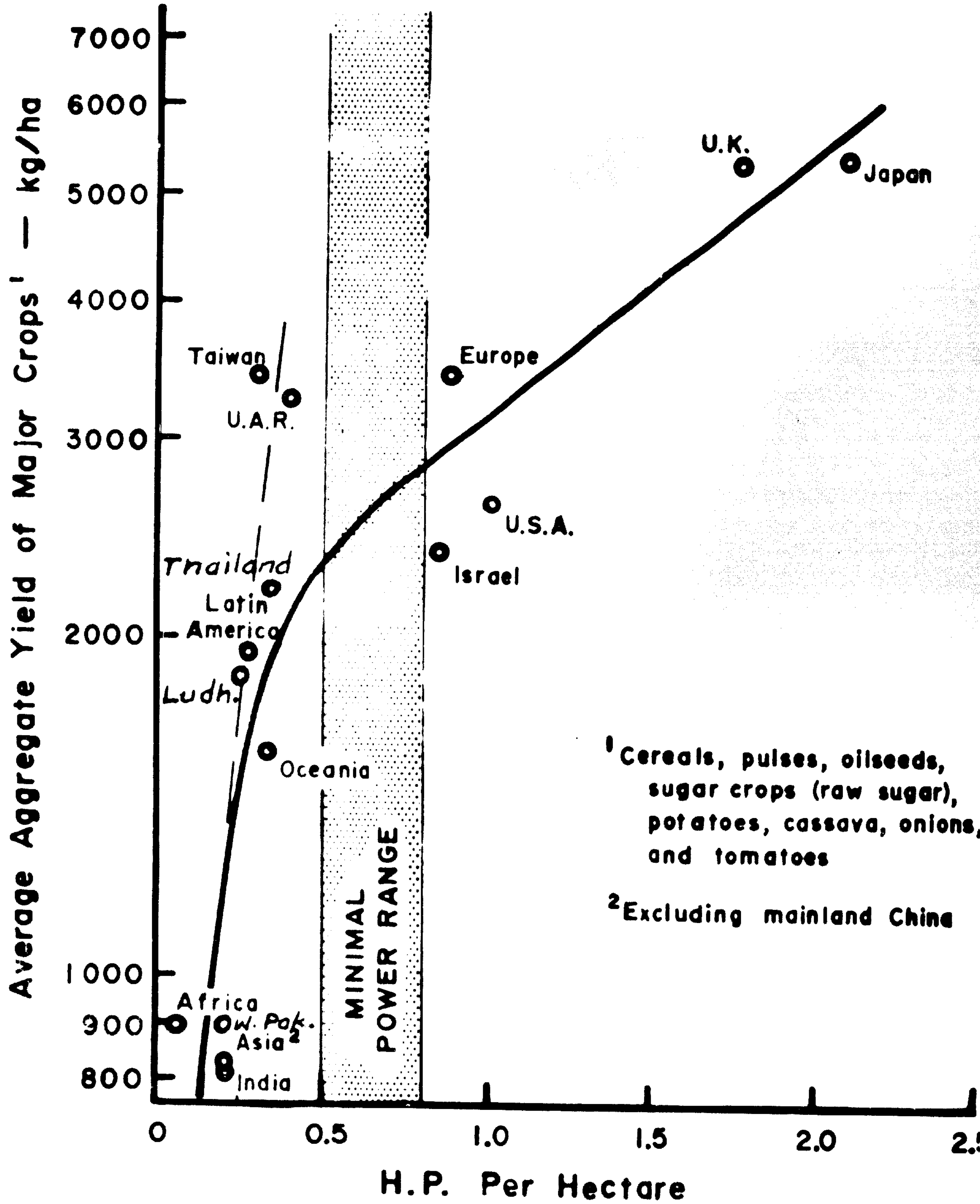
Power to Optimize Yields

The initial and most important question is: What is the minimum amount of power per hectare needed to optimize yields? An attempt to arrive at this objectively in connection with the analysis for the study of "The World Food Problem"[1] is presented in Figure 1. Horsepower per hectare was plotted against the average yields per hectare of all cereals; all pulses; all oilseeds, sugar crops (raw sugar), potatoes, cassava, onions and tomatoes for the countries, regions or continents used in Table I. Figure 1 would indicate that the minimal power per hectare for developing countries should fall within

FIGURE 1

RELATIONSHIP BETWEEN YIELDS IN KG/HECTARE AND POWER IN HORSE POWER PER HECTARE

Major Food Crops



a range of .5 to .8. The logarithmic scale for yields helps to emphasize that .5 horsepower/hectare as a marked inflection point in the slope of the curve. For calculating estimates of minimal power required, .5 H.P./Ha should be a reasonable goal. The United States of America, Europe, U. K. and Japan are probably over-powered for the optimum where production commands the main attention. These high production, high standard of living countries now look to labor efficiency and convenience as dominating criteria. It will be noted that the greatest gains in yields are obtainable more rapidly up to a power input of .5 H.P./Ha. There is considerable urgency in putting greater emphasis on increasing tractors in early stages of development. Of course, much more than the .5 H.P. would be required to maximize the production.

Data on additional countries is obviously needed to make such an analysis more reliable. Particularly, data are needed on countries that fall within the .4 to 1 H.P. class because this appears to be the critical portion of the curve. To assess the power more accurately, one should get more precise quantities of human labor, animals and tractors used in agriculture and estimates of their H.P. capability. Also, power for irrigation and stationary machine usage directly related to food crop production and preservation should be included. Also, an index of yields per hectare that weighs the data according to crop areas, tonnage and relative production energy requirements should be used. The yield-value index as developed and used by FAO[3] should be tested for this purpose.

One must keep in mind that the curve in Figure 1 does not necessarily prove that greater power applications to agricultural operations in the developing countries will contribute to increased yields--but it does give one more confidence to support the thesis, and it does provide a more scientific base for programming the needs at this stage than would otherwise be possible.

One might pose the question as to why Africa, Latin America and Asia cannot do as well as Taiwan and U.A.R., both of whom have proportionally large inputs of human power. A partial answer may be found in looking at some of their characteristics as compared with India. This comparison is made in Table III. The information was taken from "Changes in Agriculture in 26 Developing Nations"[4] and appears in "The World Food Problem"[1] report.

TABLE III

Some Comparative Characteristics of Three Countries

	Ratio of irrigated to cultivated land	Quality of potentially arable land	Health Rating	Calorie Level Percent	Educational Rating
Taiwan	61.8	1	1	102	2
India	19.9	2	3	84	3
U.A.R.	100.0	1	3	108	3

Most importantly, in Table III is the ratio of irrigated to cultivated land. Where a dependable source of irrigation water is available, timeliness is not as important in seed or plant bed preparation, except in a three-crop year system. One can spread the time to adequately prepare a good bed with little loss, if any, of yields. This is one of the reasons for puddling soil for paddy. Also, the energy requirements per unit area for tillage is less if the soil moisture can be maintained at the optimum. The tough "black cotton" soils of India cannot be tilled satisfactorily with bullocks except at a very critical moisture level. During the months preceeding the onset of the monsoon, this land cannot be tilled with country equipment and animal power. Farmers and extension workers in this area say that additional power is one of their more critical needs.

High quality land, as indicated in Table III, should be more productive for a given set of inputs. Toughness to mechanical manipulation is not included in the quality rating; yet it affects power requirements more than any one other factor. Informative sources say the soils of Taiwan are easily worked.

The general level of health and strength of the agricultural workers are also important factors.

The United Nations Industrial Development Organization is concerned with the production of tractors to be used for the growing, harvesting and processing of food crops and for transportation. They are, therefore, vitally interested in the definition of power requirements from the agricultural specialists' point of view in order to do a better job with the agricultural operations. So far as UNIDO is concerned, the needs of agriculture can be classified into three categories as follows:

1. Priority of power and equipment according to the contribution to increased production;
2. The specifications of the tractors and the accompanying equipment;
3. The quantities required per year, and over a long period.

This report will deal with these categories. At this time, however, it is appropriate to point out the importance of a more scientific means of arriving at reliable answers to the three categories above and to urge the support of UNIDO in initiating and carrying out such studies as are required to get valid answers.

Studies on the Effectiveness of Tractor Power

There are little direct research and study findings on the relationship of the amount and kind of power to agricultural production. But some rather reliable inferences can be drawn. Swamy Rao's review of research findings in India indicated that generally good tilth and timely sowing resulted in higher yields[5]. Mr. Rao concluded that in general there is a loss in yield for many crops to the extent of one percent per day of late sowing beyond an optimum period of 10-15 days. One of the references cited reported that the yield increased with the frequency of tillage up to a limit of nine plowings. This is not surprising. The problem is to bring about a concentration of power so as to produce the equivalent degree of tillage in two or three times over. How else can one accomplish timely sowing.

David Hopper and Jai Krishman analyzed input-output data on wheat in 1963 from the Ludhiana package district of India.[6] Every extra plowing with the country plow in preparing the seedbed added about 35 pounds of grain per acre. This value was highly significant and applied across the entire district. The number of plowings usually varies from four to nine, depending upon the time and power available. The problem, therefore, is getting a good seedbed quickly, and this can be done only through the application of more power per unit of time.

If all of the bullocks in Raipur district of India were put to work preparing the unirrigated paddy land of that district with the country plow, it would take about 50 days. If the mouldboard plow was substituted, it would take about 27 days. These unirrigated fields cannot be worked until some rain falls at the start of the monsoon season and the time available is about 15 days. The result is obvious; inadequate or delayed preparation on some fields because of the lack of sufficient power.

I.I. T. at Kharagpur, India, studies the effect of varying degrees of soil manipulation on yield of upland paddy.[7] The greater manipulation in preparing the field for sowing gave significantly higher grain yields and was more effective in controlling weeds. They got a 40 percent increase for the best treatment over the kind of treatment Raipur district as a whole could do because of their limited number of bullocks (discussed in the previous paragraph).

Punjab Agricultural University and Ohio State University staffs made estimates in 1963 of labor requirements for production, harvesting and marketing of crops in Punjab, India. From these estimates, man-hour requirements per acre for each month of the year was computed for a two-crop-per-year rotation of maize and wheat. The critical peak labor demand was in November when the maize is harvested and wheat is planted. The requirements were more than twice those of some months, amounting to around 175 man-hours. It is in this period, particularly, that power would contribute to timely operations. Labor wage rates are about double during this period, reflecting the market supply and demand.

Loyd Johnson[8] of I.R.R.I. in the Philippines has studied mechanization from the standpoint of utilizing power to keep the land in production more days per year. He said the following about land preparation:

> The importance of mechanized land preparation and lesser operations are still questioned by some people who would prefer to continue the use of animal and man power. However, animal or man power is slow, consumes large quantities of food, and results in loss of productive land time.

> ... If a man owns one hectare and has no work animal, he will require 200 to 333 man-hours for a single spading of the farm, or 20 to 30 days of hard labor. The weeds will be growing back during this period, and 20 to 30 days productive time will be lost, which could amount to a minimum of 200 to 300 kg of rice production. With one animal, the time will be reduced to 4 to 7 days and only 40 to 70 kg of lost production. As the size of the power unit increases, the lost production rapidly decreases. When the rainy season is short, rapid land preparation insures good weed control and best use of the rainy season. Following the harvest of the rice crop, rapid land preparation and re-seeding also make use of the residual soil moisture to grow a crop of wheat, grain sorghum or pulses.

To drill, plant and place fertilizer for optimum yields require a precision that is available on a wide-spread practical basis only with mechanical power. Take the application of fertilizer in puddled soil for rice production. Up to 50 percent more rice has been produced in India and elsewhere in the world when the ammonium forms of nitrogen are placed two inches to four inches deep, in rows nine to twelve inches apart, as compared to broadcast applications.[9] Working the fertilizer well into the puddle is the next more efficient practice. The latter is probably the most practical method. To do this job well, however, in a reasonable length of time, using bullocks and country plows seems impractical.

There are little or no data on the effect on yields of using power spraying and dusting equipment. The existing improved equipment in many of the developing nations is a pressure tank and hand pump with a single nozzle tube. It is generally agreed that the erratic waving of this nozzle, as commonly practiced as the operator walks across the field, does not give the uniformity of distribution required for good pest control. Perhaps the greatest gain in yields through power can be achieved through the use of power sprayers and dusters. Effective deposition of chemicals on plants simply takes more power than one or more individuals and one or more bullocks can generate uniformly for long periods. Furthermore, individuals and animals are more suited to tractive power.

Timely harvesting and improved harvesting and threshing equipment will not increase the yields but will help to save what is produced. The following are excerpts from the "State of Food and Agriculture, 1966" by FAO:[10]

> The choice of optimum harvesting time is an important element. Where early harvesting (paddy rice) is carried out, wastage will be high because of the presence of chalky and immature grains. Where the harvest is late, the greater number of sun-cracked grains results in a high percentage of brokens and wastage in the milled product...The Agricultural Research Institute of Gyogen near Rangoon, Burma, has shown that for long grain paddy, a loss of two percent in head rice is suffered for every day the harvest is postponed, once the grain is ripe. For the medium and short grain varieties, the figures are around 0.8 percent.

Johnson[8] made the following statement regarding the harvesting of rice:

> Harvesting is the last major operation in the crop cycle. As the grain or other crops mature, losses begin and become serious when the crop is left in the field past maturity.
>
> Studies should be made on grain losses or losses of other crops due to shattering, rat damage, etc., when left in the field past the earliest period at which harvest could occur. Once the crop is mature, the plot is no longer efficient in absorbing sunlight, and losses when occur detract from the already mature crop. When we add these losses to the losses of land production, we exceed 10 kg of palay per ha. per day cost of the idle land.
>
> The development of power operated combines and threshers to speed up the harvesting is important both to prevent losses of the crop which is already grown and also to facilitate rapid harvesting, plowing and re-planting to make use of the residual soil moisture. This aspect is of major importance to agricultural engineers in improving the agriculture of developing countries, and it is one in which mechanization can be most effective where multiple crops are possible.

A team of experts, developing a program for the Government of India to increase the outturn or yield of edible rice from paddy made the following statement with regard to harvesting:[11]

> Concentrate agricultural engineering research resources on the problems of developing mechanical paddy harvesters, threshers, and dryers to work under improved conditions of production and handling with modern storage facilities.
>
> While it may be possible to teach farmers to harvest, thresh, dry and store paddy by modest improvements of currently used techniques, it is doubtful if the level of adoption obtained would improve

milling quality of paddy very much. Mechanical threshing, at the optimum moisture content, bulk handling, off-farm mechanical dryers and off-farm fully protected scientific storage are essential to increase rice outturn to the 68 to 72 percent level but are less important at lower levels of rice outturn. Mechanical harvesting, threshing at 20 to 24 percent moisture followed by immediate delivery to a mechanical dryer and modern storage facility would permit farmers to plant a second crop 10 to 30 days quicker. These are very important gains, both to the farmer and to the nation's supply.

All of the aforementioned studies on mechanical harvesting and processing of small grain, particularly paddy, summarily point up, although indirectly, the need for mechanical power. In effect, the developing nations cannot expect much improvement in the machinery for harvesting and processing what they produce without additional mechanical power. This leads to the next section for a discussion of how improved equipment is dependent on mechanical power, particularly tractors, and vice-versa.

The Dependency of Mechanical Power

It is well to reemphasize at this point the dependency of mechanical power on the equipment it propells or causes to function, in the matter of serving agriculture. Mechanical power is little better, if any, than the equipment associated therewith. And, the reverse is true. The point might be illustrated in connection with mechanical harvesting and threshing of wheat. Table IV gives some figures on the comparative performance of four types of wheat threshing and harvesting units. These figures are estimates, generalized from discussions with knowledgable individuals and from research findings.

The important figure in Table IV is the horsepower required per hour for each maund of grain threshed, the bottom row of figures. Kindly note that mechanical power applied through the self-propelled combine is the most efficient, requiring only .9 H.P.Hrs/Md. Not only does the combine yield a clean sample, but it also cuts and handles the stalks in the field. The other machines require separate cutting, bundling and handling operations. While the power efficiency is not the only criteria in the selection and utilization of the power-equipment combination, it is important.

TABLE IV

Estimated Comparative Performance of Selected Wheat Threshing and Harvesting Units Using Mechanical Power

	12' Self-Propelled Combine	Conventional Stationary Thrasher	Japanese Paddy Thrasher	Ludhiana Power Thrasher (Makes Bhoosa)
Rated Engine H.P.	72	8	3.5	30
Mds. of grain per hour	81	8	2.5	9
H.P. hrs. per md of grain	.9	1	1.4	3.3

Priority of Agricultural Operations to Power, Mechanically

Since mechanical power and associated equipment are inseparable in planning for mechanization advancement, it follows that tractor specifications and quantity goals should be first planned with respect to those agricultural operations that are most important to a particular country's advancement.

One will find little argument, if any, against putting a top priority on the preparation of the seed and/or plant bed operation. These operations require more energy imput than any one other. Rapid soil preparation is essential in multi-cropping systems, as was discussed earlier. And, it should be pointed out that one of the better ways to increase food is through increased production per year per unit area as opposed to bring new land into production. Many of the developing countries can produce two or even three crops off of the same area.

According to a study of small tractors and their use by the Allahabad Agricultural Institute[12], farmers used the tractor more hours for pumping irrigation water than any other operation. This might lead one to insist upon the easy availability of a power take-off for pumping. However, it would seem advisable to utilize stationary power units for this purpose rather than tie up a more expensive and versatile tractor. The study also revealed the use of the tractor for carting and transportation. Regardless of its inefficiency, we most recognize that in a country where mechanical transports are not readily available for agricultural use, the farm tractor will be used for this purpose also.

If multi-cropping is a goal, one must give a high priority to the use of tractors for harvesting and threshing. In other words, getting the crop off quickly and getting the next one in quickly for maximizing the production cannot be avoided in establishing the top priorities.

As mentioned earlier, the application of chemicals to control diseases, pests, etc., is a sure way to step up yields in the developing nations. The author's experience would indicate that the most effective way to accomplish this is through a knapsack type or lightweight portable units powered by a high speed lightweight internal combustion engine of less than five horsepower. Apparently, farmers in India came to the same general conclusion, judging from the popularity of the knapsack power sprayer compared with the tractor units that were available. Tractor mounted and powered sprayers and dusters can be allocated a lower priority, initially.

In sum, tillage, harvesting, pumping water and transportation are the top priority of agricultural operations that should be considered in planning tractors for the developing countries. Planting, seeding, interculture, and spraying and dusting should be relegated to a lower priority. This is not to say that they are not important but that they can be taken care of by other means more easily than the top priority operations. For example, spraying and dusting can be accomplished with a knapsack power unit, and small grain drilling by a three-row animal drawn unit.

Some Problems Pertinent to the Introduction and Adoption of Tractor Power

No matter how compelling the argument for a rapid and substantial increase in the production and use of tractors in the developing countries, there are some sobering problems which must be faced up to. These problems are classified into six categories as follows:

1. High cost,
2. Low hours of annual use,
3. Providing a full line of power-matched equipment,
4. Attitudes towards labor savings
5. Small fields and holdings, and lack of access roads,
6. Lack of retail services, education and training.

The first three problems are very much interrelated. Actually, the cost of tractor power is low. But, in the minds of those purchasing a tractor for the first time, the cost is perhaps somewhat overwhelming. And, most certainly the cost to a nation which has many demands on its short supply of resources looks high. A rough estimate of the purchase price per H.P. of the larger tractor (30 H.P.) in India is lower than a small (10 H.P.) tractor and a pair of good bullocks. John Balis[13] of the Allahahab Agricultural Institute estimates that the cost of operating the larger tractor is lower. These data appear in Table V.

TABLE V.

Estimate of Horsepower Costs by Source

	Rough Estimate of Initial Cost per H.P.	Operating Cost per H.P. Hr.
Bullocks	$500	$0.15 - $0.22
10 H.P. Tractor	$200	$0.08 - $0.19
25-30 H.P. Tractor	$120	$0.06 - $0.16

The hourly cost of operating a tractor is greatly affected by the amount of use. Hourly costs are lowest at 800 hours or more of use per year[14]. The author estimated, on the basis of data available, that in West Pakistan the hours of use were no more than 500-600 annually. And much of these occur, so it appears, in such operations as transportation.

The low hours of use are attributed, to a large degree, to the lack of matched equipment and the education and training necessary to accompany the tractor's availability. It is questionable whether government officers are really aware of what power and equipment will contribute to increased production. For example, do they know that good drilling equipment and methods of use will increase wheat yields ten percent or more, and good planting, forty percent? Yet, data to support this fact have been documented by trials and tests in India.

Many government officials look upon tractors simply as labor saving items and, therefore, understandably so, are reluctant to allot scarce resources to their procurement and use. But, actually, this is not the dominating justification for tractor power, as was brought out above and previously in this section.

Questions have also been raised regarding the inhibiting aspects of the small fields and holdings and the inadequacy or lack of access roads to the practicality of mechanization in the developing countries. By and large, these obstacles will be taken care of by the people concerned in a normal course of events, if and when tractors and equipment are made more readily available. The more urgent problem confronting the world is one of producing, servicing and demonstrating machines as one of the "yield-increasing" inputs, of educating people in their proper use and care, and of providing adequate service. Most importantly is the education of responsible government officials so that they act on the basis of facts and not opinion. These later problems are serious and will be discussed separately in a later section of this report.

ESTIMATE OF TRACTORS NEEDED

There are three major regions that encompass the developing nations and the accompanying food problem. These are Latin America, Asia and Africa. It seems appropriate, for this paper, to use these three broad regions for making estimates of tractors needed. The data and calculations that follow were taken from the author's analysis of need made in connection with "The World Food Problem."[1] Some of the comments and discussion are verbatum from that report.

History of Tractors on Farms

It would be well to note what Latin America, Asia and Africa have been doing about their tractor population in the past. It gives a good starting point in projecting future needs. Accordingly, data on tractors on farms used for agricultural production in these three regions is presented in Figure 2 for ten years, 1955 through 1965. The data were taken from FAO's Production Yearbooks.[2] The net growth from 1955 through 1965 of tractors averaging 30 H.P. in size on farms was 12,000/yr in Asia, 9,500/yr for Africa, and 27,800/yr for Latin America.

Projected Realistic Growth Rates

To estimate realistic and achievable growth rates for tractors, it would be well to use power per hectare as a starting point. This is used in view of the relationship of power to yields, as previously brought out.

The additional power per hectare needed for Latin America, Asia and Africa is presented in Table VI. This assumes a minimal level of .5 H.P./Ha., and that the labor force will double by the time these regions meet the minimal level.

FIGURE 2

NUMBER OF TRACTORS USED IN AGRICULTURE
(WHEEL AND CRAWLER)

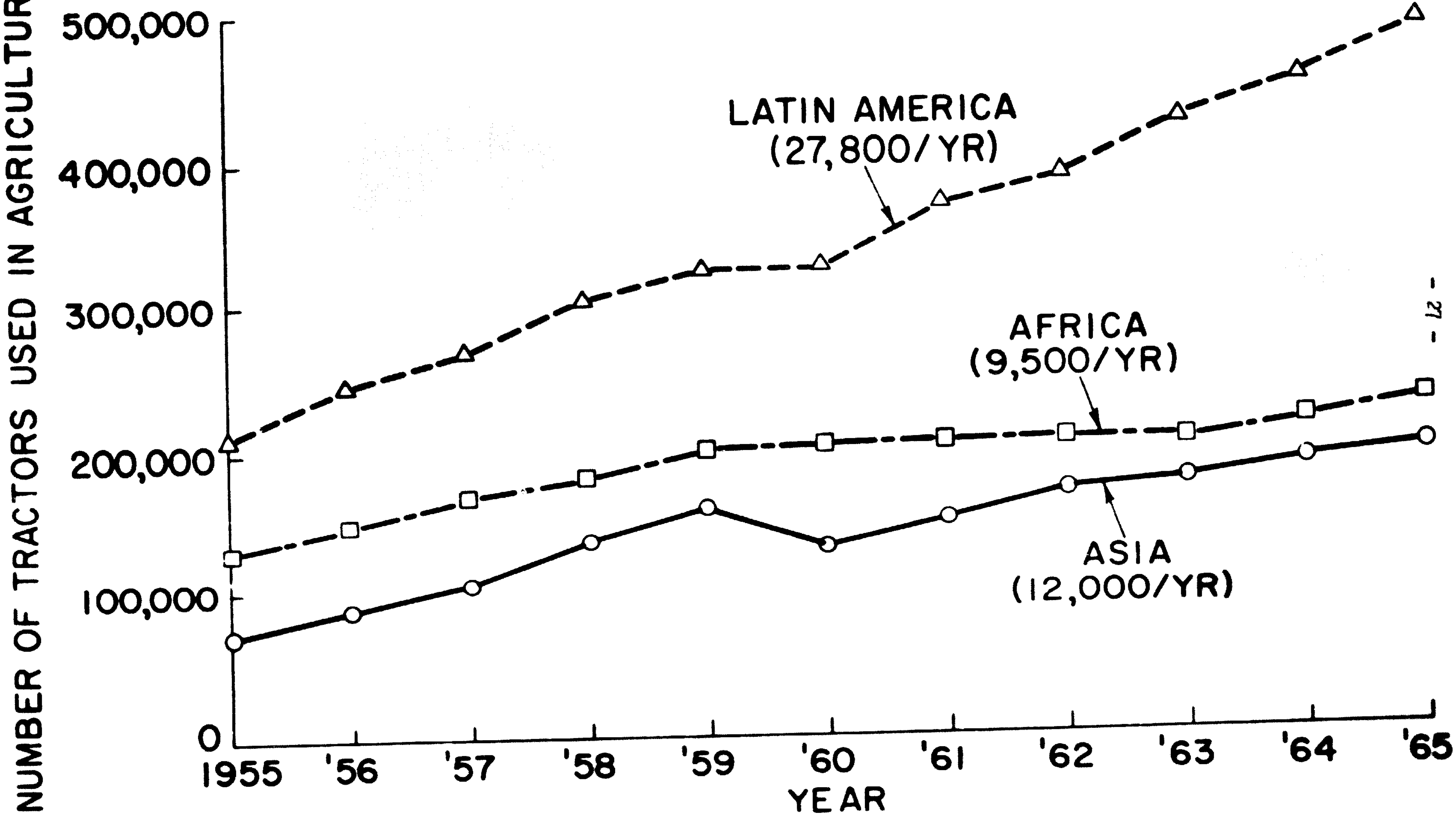


TABLE VI

Existing Power (H.P./Ha.) and Amount Needed to Meet Minimum Goal of .5 H.P./Ha.

	H.P. per Ha.		
	Latin America	Asia	Africa
Existing			
Human	.02	.05	.01
Animal	.07	.10	.01
Tractor--including garden types	.18	.05	.03
Additional Needs			
Human (Assume labor force will double)	.02	.05	.01
Tractor	.21	.25	.44
Total	.5	.5	.5

It is assumed that the power to be added, other than the labor increase, to reach the minimum would have to be met by mechanical power. The amount that labor can add is insignificant, even with a doubling of the labor force, as is shown in Table VI above. The only other alternative is animal power. Increasing animal power would be, of necessity, a slow, frustrating process, very expensive in capital costs and maintenance, and the final success of such an effort doubtful. The capital cost per H.P. for work animals is higher than mechanical, as was brought out previously. Furthermore, this direction is not exciting and is opposite to what the progressive farmer wants and will go. Today he is tractor-minded.

Latin America can probably fill its needs at a reasonable tractor growth rate. However, the number of mechanical power units, accompanying service and educational activities required for Asia and Africa to meet the .5 H.P./Ha. minimum would be overwhelming indeed. For these two areas for the forseeable future, it would be advisable to project an achievable tractor production growth rate of six percent compounded with a depreciation rate of seven percent. In other words, determine the quantities of tractors needed by using a six percent compounded growth rate rather than by using the .5 H.P./Ha. goal. The latter approach can be used later if and when a valid equation has been developed for a yields vs power curve and if and when these continents demonstrate their capability to move forward in the area of power and equipment at a rate greater than six percent. The six percent rate will be modest in comparison. Further, it would be hazardous to project an ambitious program without a more scientific base for establishing the minimum power goal.

Also, one must provide for tractor fuel and one should see that the repair and maintenance services are available and adequate. These services should parallel the expansion of tractors.

Table VII gives the quantities required by the end of successive four, six, ten and twelve-year periods, using the six percent compound tractor production growth and seven percent on-the-farm depreciation rate.

The tractor production in numbers appearing in Table VII was computed using an average size of 30 H.P. This does not mean that this is the only size to be imported and/or manufactured. On the contrary, a country should manufacture a range of sizes, perhaps from 6 or 7 H.P. garden type to the 50, 75 and even 100 H.P. sizes, both wheel and crawler types. The product mix will need to be determined at the national level.

In Figure 3, the number of tractors (averaging 30 H.P.) on farms in Latin America, Asia and Africa have been plotted in condensation for 1965

TABLE VII

Number of Tractors, Averaging 30 H.P.* to be Manufactured During the Periods Indicated
(6 Percent Compound Factory Production Growth Rate)

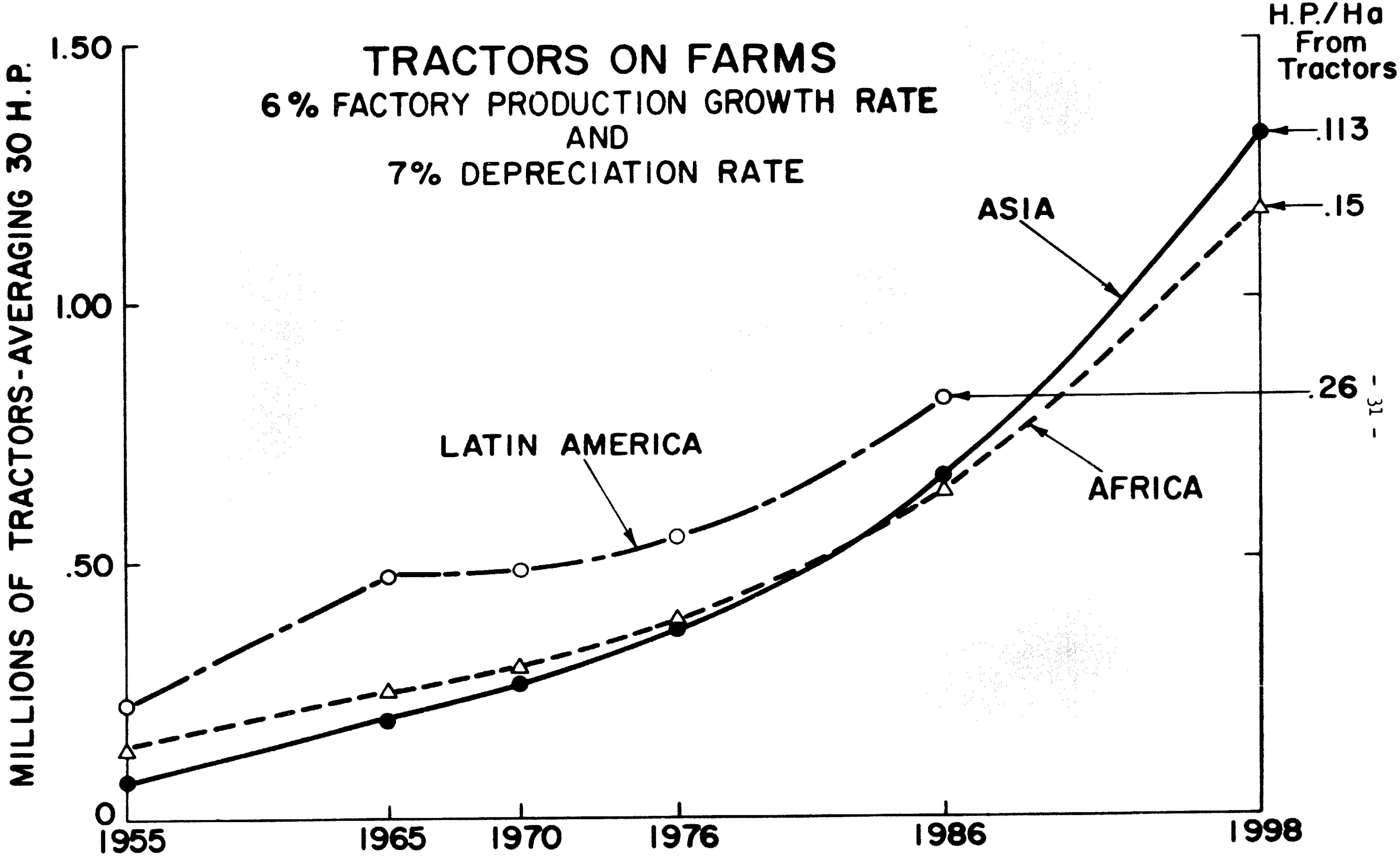
Period	Number of Tractors (30 H.P.)		
	Latin America	Asia	Africa
1. 4-year period ending 1970	145,000	123,000	119,000
2. 6-year period ending 1976	291,000	248,000	239,000
3. 10-year period ending 1986	761,000 Minimal power achieved in 1986	665,000	641,000
4. 12-year period ending 1998		1,523,000	1,468,000

Analysis

	Latin America	Asia	Africa
1. Total number of tractors to be manufactured	1,200,000 (in 20 years)	2,560,000 (in 32 years)	2,467,000 (in 32 years)
2. Net on Farms (Existing population + new tractors - depreciation losses)			
Numbers - total	828,000 (in 1986)	1,318,000 (in 1998)	1,274.000 (in 1998)
3. Net H.P./Ha.	.26	.113	.15
4. Percentage of the total additional H.P./Ha. tractor power needed (Table VI)	124%	45%	34%

*Includes all sizes and types, from the small garden type to the largest crawler and wheel. Does not include power tillers recommended for wet land operations. Estimates for power tillers appear later and are in addition to the above tractors.

FIGURE 3


TRACTORS ON FARMS
6% FACTORY PRODUCTION GROWTH RATE
AND
7% DEPRECIATION RATE
MILLIONS OF TRACTORS-AVERAGING 30 H.P.
1.50
1.00
.50
0
1955
1965
1970
1976
1986
1998
H.P./Ha From Tractors
.113
.15
.26
ASIA
AFRICA
LATIN AMERICA

through 1965, and projected beyond to 1998. For the future, these curves have been constructed using a six percent factory production growth rate and the seven percent depreciation rate, as mentioned previously. Latin America is plotted only to the year 1986, the date it will meet its minimal total need of .5 H.P./Ha. These growth rates are considered realistic and achievable.

The total number of tractors to be added to each of the regions and for the time period indicated, appear in Table VIII. To this table has been added power tillers since they are an important power unit in the product mix of the developing nations. Paddy is an important crop in these countries. And the power tiller is an effective unit for wet land production. The contribution of power tillers to the net horsepower per hectare will not significantly change the figures appearing in Table VII. The estimates for power tillers are programmed on the basis of their use only for one-half of the land area in paddy. The remainder of the area in paddy is left for tillage by the conventional type of tractor and animal power, together with appropriate equipment. All paddy is not produced under wet land conditions.

TABLE VIII

Summary of Tractors and Power Tillers Needed, by Region and Time Period

Number Needed	Latin America (20-year Period)	Asia (32-year Period)	Africa (32-year Period)
	(Millions)	(Millions)	(Millions)
Tractors average 30 H.P.	1.20	2.56	2.47
Power tiller	.27	1.9	.047

ESTIMATE OF RETAIL COSTS OF TRACTORS NEEDED

A summarization of the retail costs for the added tractors and power tillers for each region for each of the four periods is given in Table IX. The tractor was computed using a value of $3,800 and the power tiller at $900. Obviously, these values change with time and so adjustments will need to be made from time to time.

Although the total retail cost of these inputs seems large, the amount per hectare of land is reasonable. The last two lines in Table IX give the total investment over a period of 32 years (20 years for Latin America) per hectare. It averages out to be about $37.00 per hectare or slightly more than $1.00 per hectare per year; $50.00 for Latin America; $33.00 for Asia and $38.00 for Africa. This is really an insignificant investment in terms of what it will do for agriculture and the country. The average may be misleading, however, since each hectare would not necessarily receive a proportional share because the types of power and equipment and crops would influence the investment on a farm level.

In order to make some sort of comparison, the United States (48 states) during the 20-year period from 1940 to 1960 increased its assets in machinery (tractors and equipment) and motor vehicles (includes 40 percent of the value of automobiles) by $15.4 billion.[15] This amounts to about $83.00 per hectare of arable land and land under permanent crops, or about $4.10 per hectare per year. Normally, the equipment needed to accompany the tractor will at least equal the value of the tractor.

So the level of investment in mechanical power suggested for the developing countries is not too out-of-line with what the developed countries have spent during the periods of their growth.

TABLE IX

A Summarization of Retail Costs by Type of Power , Area and Period

	Millions of U. S. Dollars*		
	Latin America	Asia	Africa
4-Year Period Ending 1970			
Tractors	550	470	450
Power Tillers	50	220	10
Total	600	690	460
6-Year Period Ending 1976			
Tractors	1110	940	910
Power Tillers	70	320	10
Total	1180	1260	920
10-Year Period Ending 1986			
Tractors	2900	2530	2440
Power Tillers	120	530	10
Total	3020	3060	2450
12-Year Period Ending 1998			
Tractors		5790	5580
Power Tillers		640	20
Total		6430	5600
Total for Period	4800	11,440	9430
Grand Total = 56,290			
Investment/Ha.	$50	$33	$38

*Figures are rounded to the nearest ten million

ESTIMATED CAPITAL REQUIREMENTS FOR TRACTOR MANUFACTURING PLANTS

The plants for manufacturing tractors, of the types and sizes important to increasing agricultural production, are varied and complex--so much so that it is impossible to plan precisely for the internal needs without a detailed and time-consuming study. And such a study should be done on a national basis, not regional. An approximation on a regional basis has been attempted.[1] The approach used was to estimate capital cost on the basis of the annual value of sales that were summarized in Table IX.

The capital costs were computed at 100 percent of the total annual sales. In other words, there is, in all likelihood, a direct relationship of plant costs to sales.[16] The costs computed by the percentage of sales approach would include warehousing, services such as electricity, replacement of production tools as they become obsolete and ancillary plants. Using this method, the capital costs for Latin America, Asia and Africa for tractors and power tillers are shown in Table X. They are inclusive and, as such, are considered to be realistic. These values were computed several years ago and will have to be adjusted from time to time to accommodate rising costs.

TABLE X

Capital Requirements for Tractor Manufacturing Plants

	Millions of U. S. Dollars			
	Latin America	Asia	Africa	Total
Tractors	228	304	293	825
Power Tillers	12	54	2	68
Total	240	358	295	893

*Calculated at 100% of annual average sales over the 32-year period for Asia and Africa and 20-year period for Latin America.

The capital costs of manufacturing plants appearing in Table X can be prorated for each region among the 4, 6, 10 and 12-year periods as indicated in Table IX. If this is done, we would have a reasonable distribution of the total capital investment that will be required over the 32 years ending in 1998 for Asia and Africa and the 20 years ending in 1986 for Latin America. The 4-year period ending in 1970, as indicated in Table IX, is rapidly nearing its end. The figures were prepared for "The World Food Problem" [1] study several years ago. There is little value in altering them at this time. It would be interesting to know if the three regions actually invested in tractors at the end of 1970 to the extent proposed. The author would guess that they did.

Some of the existing factories for the production of agricultural power in some of the developing nations are handicapped in achieving a high productive efficiency and the rated capacity of the plant because of inadequate imports of critical components or materials. These components are not now being manufactured in a developing country for various reasons such as the inadequacy of specialized materials, tooling or skills. Imports usually amount to 10 to 20 percent of the cost of the tractor.

It is recommended, therefore, that in the initial stages of building up plant capacities in the developing nations, increased imports of critical components should command the highest priority. Plants to produce these critical components can follow later. In other words, give first attention to increasing the capacity and efficiency of plants already in existence.

SELECTION OF TRACTOR SPECIFICATIONS

Introduction and Results of Studies

One of the difficult questions facing a developing country that has decided to manufacture and/or import mechanical power is the size and type. This question, in the author's opinion, has not been given the studied consideration that its importance would indicate. If a nation is seriously concerned with increasing its food production, then it must be seriously concerned with mechanical power of such specifications that will allow them, in fact, to maximize their production at the lowest possible cost.

Knowledgeable individuals will agree that not all forms of mechanical power lend themselves to efficient agricultural production. A case in point is the utility type of tractor that some countries have adopted. A utility type of tractor is suitable for plowing and breaking land, for transportation and for belt work. But it is not satisfactory for row crop farming. For successful row crop power farming, the tractor's tread, both front and rear, should be adjustable, say, in increments of four inches. This adjustability is needed because it is unrealistic to expect farmers to be able to adopt a uniform width for all row crops. Each row crop has row spacing and plant population, as well as fertility rate, etc., that will give the maximum yields.

Another important feature to consider is the distance from the ground to the lowest point of the tractor directly over the crop row. This clearance affects the ability of the tractor to travel astride two or more rows for such operations as interculture and spraying without damaging tall plants. The minimum clearance should be about 19 or 20 inches.

There are few studies made in the developing countries to reveal the optimum specifications of power and equipment.

In a talk to the Indian Society of Agricultural Engineers[23] in 1967, the author emphasized "Evaluation" as the key to advancing mechanization. He said the problem inhibiting rapid progress in increasing the extent and use of modern power and equipment in the agricultural input - mix is selection, adaptation and evaluation. It is not inventing new equipment and principles. Rather, it is one of selecting kinds of equipment that have proven out elsewhere and adapting them to the situation in India. To select and adapt requires evaluation. It is not difficult to select and adapt from among the world's collection. The more difficult problem is to conduct evaluations that are meaningful and valid. This, then, is the real key to India's advancement in power and equipment systems for agricultural production.

In most instances we are failing to make our evaluations factual, complete and comprehensive. And we are failing to analyze the data statistically, to determine its validity and to show how to improve field tests. Too many of our evaluations are based upon opinions, formed by simply observing the machine in operation for a relatively short period. Too many of our evaluations are based upon measuring only one or two factors; for example, the draft. And, when we do collect data, too few and scattered readings are taken and the trials are not replicated.

Most machine systems can and should be evaluated on the basis of four major performance components as follows:

1. Machine performance; for example, the acres per hour,
2. Power performance; for example, the horsepower hours per acre,
3. Labor performance; for example, the man-hours per acre,
4. Economic performance; for example, the overall economic analysis giving the total input costs and resulting value to the product and process.

Chancellor[22], in a paper to the A.S.A.E. in 1967, established an economic basis for making decisions on the size of tractor that should be purchased. His analysis does not take into consideration, however, the benefits in terms of agricultural production, etc., resulting from the amount or effectiveness of the power. What is greatly needed in the developing countries are field trials, carried through to a yield stage, to arrive at a cost/benefit analysis.

A tractor evaluation project[12] was conducted by the Allahabad Agricultural Institute. This survey-type of research study was confined to tractors in the range of 5 to 15 H.P. and, among other objectives, was to determine their physical and economic performance. The study concluded that small tractors should be introduced and suggested four models along with guidelines for design.

There have been many attempts to design tractors specifically for the developing countries, such as the work done at the N.I.A.E. in England. While these endeavors are commendable, there is badly needed studies that evaluage the specifications including power. At least, these designs should be put into meaningful, scientific, comparative studies with conventional designs.

Range of Sizes and Types to Meet the Varying Situations

While studies have not specifically pinpointed the exact optimum specification for agricultural tractors, we can proceed on logic, based upon wide experiences at home and abroad. In the author's opinion, a study aimed specifically at deriving optimum specification should not command a high priority. Too many other mechanization studies, such as yield per acre to power per acre relationships, are more important.

To begin with a developing nation, as in the case of developed countries, have a wide range of farming situations and opportunities, such as soil types, size distribution of farms, size of fields, crops suited for production, level of mechanical aptitudes of those who work in agriculture, and contract opportunities. A simple example to illustrate the variability of the situation and opportunities can be given with respect to West Pakistan.[17] A little over one-half of the cultivated area in West Pakistan is within the 0-25 acres per farm class and is owned by 4,472,492 cultivators - roughly 6.3 acres per owner. The remaining area is owned by 387,487 individuals - roughly 54 acres per owner.

As a generalization, the 0-25-acre farms in West Pakistan can be classed for animal powered farming, and the 25-acre and above farms for tractor power. This is not to say that a sharp line of demarcation exists between the less than 25 acre group and the more than 25 acre group. For example, there are economic opportunities for a blending of bullock and tractor power, and for contract usage of tractor power. A farmer with one 30 H.P. tractor and one pair of bullocks can put in 75-100 acres of wheat by using the tractor for seedbed preparation and the bullocks for pulling a 3-row grain drill. The grain drill can follow and keep up with the seedbed preparation. Incidentally, this is an excellent example of matching equipment and the job to the amount of power available. Another example occurs frequently in the developing countries. A farmer with, say, 20 acres buys a tractor, does his own field work, and then hires out to his neighbors. The author has talked with small farm owners who paid for their tractor in the matter of a few years from the custom work--and they had the benefit of the superior power on their own farm.

In West Pakistan there are about 14,000 owners whose farms have 150 acres or more of farming land. Some of these owners have farms of thousands of acres each. These farmers should not be using small tractors or animals except as secondary or supplemental power sources. They are really large commercial operations and well adapted to large, powerful tractors. It is worth repeating that the original cost per horsepower and the operating cost per horsepower is lowest in the case of the larger tractor. The low operating cost assumes that the tractor will be kept operating for a relatively large number of hours per year, a fact that is appreciated and adhered to by the large farm operators.

The conclusion is that a wide range of tractor sizes and types are needed in any developing country, as well as in the developed ones. The power tiller, the 5 - 15 H.P. size and the 30 - 100 H.P. and over, particularly of the row crop type, are needed. The larger tractors, such as 100 H.P. will be used less for row crop work and more for tillage, land shaping, combining, etc., and, therefore, can be of the utility type. However, the row crop is still preferred in the larger sizes as well as small.

Establishment of Priority

Any developing nation is short of resources and, accordingly, must make hard decisions as to the general allocation of these resources. It is axiomatic that they make the allocations mainly on the basis of the extent each will contribute to the nation's development and needs.

Although agriculture's need of a wide range of power sizes and types was stressed, one cannot expect all to be immediately adopted and provided. Some hard priorities must be established.

As a top priority, the author would suggest the larger tractor having at least 30 H.P. and of the row-crop type. A second priority would go to a tractor of around 60 to 70 H.P., also row-crop.

A third priority would be divided between power tillers of 7 or 8 H.P. for the rice farmer, and a general purpose tractor of around 15 H.P. for dryland farming. The latter should be of the row-crop type.

The lowest priority would be assigned to the development of tractors having unusual configurations, such as three wheels, engine in the rear, etc. By and large, these off-beat designs have not worked out. Furthermore, the developing nations cannot afford to spend their precious resources for develompental activities along this line. They would be better off to adopt types and configurations that are successful and widely used elsewhere. The development of new types can be reserved for later stages in their growth, when they can afford it.

A top priority should be assigned to tractors of the conventional configuration and style that are sophisticated in design and options. For example, it would be highly desirable to have a multiple cylinder engine with self-starting and hydraulic controls. In this advanced world of general affluence and excellent communications, the knowledgeable farmers, leaders of the farming community, want and will pay for the best. These are the farmers, too, who will make the greatest gains in increasing production, if they have the essential inputs.

THE PROVISION OF COMPREHENSIVE SERVICE

The Responsibility of and Need for Supplying and Servicing Farm Tractors

There are two good reasons for markedly stepping up the manufacture and/or importation of tractors for agricultural production in the developing nations. The first, to increase agricultural production was covered previously in this paper. The second is the economic advantages of dealing in larger quantities. But supplying agriculture with tractors carries an additional responsibility. This responsibility is particularly substantial when large numbers are involved. The tractors will require fuel, supplies and rapair parts. A network of sales and services will have to be established. And, most importantly, education and training of dealers, service men and operators will be required.

Harold H. Kitching[18], in a paper presented to A.S.A.E. in 1967, made the following statement:

> The farmer in less-developed areas, when purchasing his first tractor, faces a completely different and much more difficult problem than his more fortunate counterpart. Before purchasing his first tractor, the western farmer usually had been doing his work with at least two or more, quite often four, quite strong horses; and he had a complete set of tillage, seeding and harvesting machines to utilize the power of these animals.
>
> With his first tractor, he usually purchased only one implement, most often a plow. In most cases, however, he adapted all his existing horse-drawn equipment for use with the tractor and thus with a low investment in implements, he was able to use his tractor for all production operations with primary tillage right through to harvesting and transport of his crop to storage or to market.
>
> Compare this with the position of the farmer in the lesser developed countries. When he purchases a tractor, his existing

implements are all of the two bullock or one camel size and usually consist only of a wooden plow, a wooden plank for smoothing and a bullock cart. If he is in an irrigated area he will also have some type of animal-powered water lifting device. None of these indigenous implements are suitable for operation with a tractor. Also, remember that his wooden plow was a multipurpose tool which he used for primary and secondary tillage, seeding and inter-row cultivation. It required no spare parts other than a locally forged point. It had no adjustments, required no lubrication and needed no tools whatsoever to maintain it.

Sales and service to accompany the expansion of mechanization, whether in developed or developing countries, is an old subject about which much has been written and spoken. Articles on this subject are many, some of which are surely well-known to the reader. It is the purpose, therefore, of this section not to rehash this material but to attempt to add a few new dimensions to our thinking along this line. For there is little question about the vitalness of the subject, and most people will agree that too little is being done about it at the present time.

Comprehensive Service Defined

The term "Comprehensive Service" was used by A. B. Behr and F. A. Mills[19] to define all of the services and supplies that will be needed by tractor farmers. It is a term that describes the needs appropriately. These needs include, in the author's opinion, fuel, oil, tractors and equipment, repair parts, service of mechanics, preventative maintenance, demonstrations, educational and training programs and credit. Unless adequate comprehensive service accompanies the growth in tractors, the anticipated advantages, that is, increased production and economic, will not in all likelihood be forthcoming.

Farmer-Orientated Services

Fundamentally, comprehensive service is for the farmer and, therefore, should be organized and implemented with the farmer in mind. John S. Balis[20], in a paper presented to the Indian Society of Agricultural Engineers, really recognized this fundamental point when he talked about the basic principles of sales and service facilities. He said:

> The sales and service organization must provide the farmer with three kinds of services to ensure efficient and dependable operations of the equipment being sold. First, the farmer needs knowledge about what the machine will do for him and how he should use it to get the job done properly. Second, the farmer expects the dealer to provide at least part of the service and any spare parts required during the lifetime of the machine. Third, the dealership must become a long term service company for the farmer, supplying additional machines at reasonable cost as the farmer changes to new practices. The manufacturer or his selling agent must ensure that these services are adequate to ensure that the farmer can get the performance from the machine that is designed and built into it.

In the developing nations, often entrepreneurs and government officials think in terms of non-competition, off-the-farm practices and economic gains related to the business of supplying the farmer. Rather, they should be orientated in the direction of the farmer's business of supplying food for the nation. The author has noted this lack of proper orientation, particularly with respect to government operated manufacturing plants and connected sales and service facilities. A certain piece of equipment, for example, was obviously a poor performer in the farmer's field, as judged by unbiased experts. Yet this piece of equipment continued to be produced and almost forced on the farmer through subsidies, even when its deficiencies and defects were called to the attention of the responsible officials. Also, the replacement parts for this particular piece of equipment were not standardized to fit, nor were they easily and readily available to the buyer. The emphasis in the case just cited was obviously on what was best, or, shall we say, less disruptive of the tranquility of those who work for the government agency.

Take the tractor as another example. The government of a developing nation may enter into an agreement with a foreign company and/or country for the manufacture of a model which is in fact and proves to be unsuited to do an acceptable job of carrying out operations in today's agriculture. Yet, because of "face-saving" and perhaps economic reasons, they continue to manufacture and distribute the tractor, to the detriment of the farmer, the one on whom they are depending for increased production. Perhaps the tractor was one that was actually obsolete in the contractor's country and was simply transplanted in the developing country as a good riddance. Such actions and inactions as cited above are not logical when one thinks in terms of the seriousness of the food problem, worldwide.

We must keep in mind that the farmer is, in the final analysis, responsible for achieving the food production requirement of the country. Therefore, the required inputs, including tractors and associated equipment, and the services in connection therewith, are for the farmer's food production factory. The farmer is the customer. He must make the decisions regarding the inputs he buys, as do other industrial factory managers throughout the world. A parallel to this requirement is the need for enhancing competition among private concerns. If they are in competition and are free to profit from their efforts, then their services to the farmer should be superior and most economical. We must keep these principles foremost in our minds in planning and implementing comprehensive service.

Modern Management Practices Applied to Comprehensive Service

If the farmer is in fact to be benefitted from the comprehensive service, then those who finance and operate the service business will in turn be benefitted. Perhaps no moral principle is more benefitting the establishment and operation of comprehensive service than the following:

> Any business arrangement that is not profitable to the other fellow will, in the end, prove unprofitable to you. The bargain that yields mutual satisfaction is the only one that is apt to be repeated permanently.*

The investment required in providing adequate sales and service will be larger, in all likelihood, than the amount required for the production of tractors. The gross volume of business will likewise be greater. Properly handled, this business can be an economic asset to the country and to those so engaged. Take the fuel requirements in Asia as an example. If Asia achieves the projected growth rate of tractors in 1998, less than 30 years from now, her fuel requirements for tractors alone will amount to more than 1¼ billion U. S. gallons per year. This calculation assumes one-half rated H.P. output and 800 hours of annual use. And fuel is only one small aspect of the total service business that will be required.

The first requirement, that of having the comprehensive services farmer oriented, must now be matched with modern management practices. These modern management practices involve the following:

1. Economical tractor and equipment that will help to increase production,
2. Effective demonstrations to show the benefits,
3. Adequate and timely credit, and
4. Reliable after-sales service.

---

*B. C. Forbes, Forbes Magazine, August 1, 1968.

Unless the tractors and the associated equipment are, in fact, economical, it is questionable that they will grow substantially in popularity and use. There are other benefits of the tractors, of course, as has been brought out earlier; but the overriding and fundamental benefit must be economic. It is this benefit we must look at critically when selecting, designing and marketing agricultural tractors and equipment. An example of a cost/benefit analysis can be cited with respect to a modern grain drill that was studied in depth in India.[21]

> The average gain of 3.4 mds/acre demonstrated in Ludhiana would enable a farmer with two acres under wheat to break even on the purchase of a drill.* A farmer with four acres under wheat would earn 24 percent on the investment. For a more conservative picture, assume a 10 percent yield increase is achieved over the present Ludhiana average of 24 mds/acre. Purchase of a drill would then bring a 13 percent return to a farmer with four acres under wheat, a 28 percent return on six acres, and 59 percent on ten acres. If the drill is used on 15 acres, it would pay off its initial cost in one year's time.

The author would make a strong appeal to encourage similar studies with respect to tractors and their associated equipment

Convincing Demonstrations

If the tractor and equipment will, in fact, increase production and result in other benefits, then these must be determined and convincingly demonstrated. Otherwise, how can a farmer choose intelligently? Or, for that matter, how can a government make decisions about producing tractors?

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*These calculations are based on initial delivered cost of the drill @ Rs. 600; depreciation over ten years; interest on investment at 8%; annual maintenance expense @ Rs. 30; average wages and bullock charges now prevailing in the respective districts; and wheat prices to the farmer @ Rs. 18 per mound.

The most effective demonstrations are those that are comparative with respect to sizes, principles of operation, and brands. Whenever applicable, the demonstration should be carried through to the final yield stage because yields per acre and production are the overriding needs. Furthermore, it is usually necessary to have the yields per acre in order to make a satisfying cost/benefit analysis.

Inasmuch as comparative demonstrations are desirable, and inasmuch as it is best to have the manufacturer's representative adjust and operate the tractor and equipment during the demonstration, government officials concerned with extension education are best qualified to plan and manage such demonstrations. In fact, conducting comparative demonstrations along with teaching the what, why and how of tractor operation would seem to be the government's main role in comprehensive service.

Emphasize Credit, De-emphasize Subsidies

Government's second role in the matter of furthering comprehensive service is providing adequate and timely credit at competitive rates. Morse and Giles[21] emphasized the value of credit and de-emphasized subsidies as ways to move mechanization forward. The substance of their discussion appears in the following paragraphs, some parts of which are verbatim.

It is believed that strengthening credit, particularly medium-term credit instruments for farmers, especially on small-medium holdings will contribute more towards rapid and economical modernization of agricultural equipment than any direct subsidy program. Some cooperative banks as well as private scheduled banks have already broken ground in financing the purchase of agricultural equipment in some countries.

Adequate after-sales service is extremely important in developing the market. In an environment of continued progress, newly-introduced implements will have a low user-intensity in the initial stages. But the kinds of repair parts needed to service farmers adequately will be the same in the initial stages as later on when the user-intensity is greater. The local dealer should stock at least one or more of each repair part to serve the relatively few farmers who buy in the initial stages. Stocking costs will be high and the turnover low - which often is not an economical investment. Yet timely service is one of the factors influencing the successful introduction of any new implement. Any implement which is out of commission for lack of repair is not an economical investment for the farmer. Nor will it give the desired production increase. Timeliness of agricultural operations is an important factor in achieving higher production.

Consideration, therefore, might well be given to more liberal medium-term credit provisions for manufacturers which would enable them to produce parts and make them available to dealers for stocking on easy terms. Since the number of individuals involved would be far less than in a direct subsidy program, the plan would be more managable, require less paper work and be less expensive to administer.

Adequate after-sales service also requires mobility. Here, again, credit and assistance might be offered to manufacturers and local representatives to purchase needed transports.

A program of assistance is intended to help advance mechanization along profitable lines more rapidly than might otherwise be possible. It is questionable, however, whether a direct subsidy program will contribute effectively, if at all, to this objective.

A study in India with users of a new drill confirmed that a subsidy program tends to impose a barrier on the growth of the agricultural implements industry. One farmer who had invested Rs. 6000/- in three deep wells hesitated over the Rs. 172/- price of a disk harrow and the Rs. 666/- delivered price of the seed drill. He did not acknowledge the economic benefits of the drill. He concentrated his attack on getting it for half price - since there are subsidies on other equipment. In other words, real cost/benefits tend to be ignored under this situation. In fact, they cannot be adequately measured or appreciated by the farmer because the subsidy distorts real costs.

A manufacturer who seeks to enter a market by relying on subsidy sales would find, after the first year or two, that subsidies tend to set an upper limit on market volume. Farmers who are not on the subsidy list this year postpone their purchases, thus dampening demand. The market would grow much more rapidly if emphasis were placed on cost/benefit advantages.

In some instances reliable private manufacturers have been prohibited from selling through government channels at a subsidized rate because the state government is in the manufacturing business too and it needs to move its own products. This practice tends to destroy open, competitive markets where "the farmer decides." As a result, the manufacturer who is favored with government acceptance of his product has no incentive to improve it for competitive purposes.

Direct subsidies on agricultural equipment have no impact whatsoever on the improvement of management practices. Funds directed to strengthening industrial counseling, market research, and management training would have much more positive, long-range effects on modernizing agricultural equipment and, thus, contributing to higher food production.

In sum, this section emphasized that service to farmers should be (a) comprehensive, (b) farmer oriented, and (c) managed by modern practices and techniques. An outline of the kind of assistance discussed in this section and recommended for rapid advancement of agricultural mechanization, along with a designation of the agency most responsible for each type of service, appears in Table XI.

TABLE XI

Outline of Comprehensive Service

Category	Description of Type of Service to Provide to the Farmer	Agency Most Responsible
Before Sales	Knowledge, particularly cost/benefit of the tractor and associated equipment, and how the equipment should be used and cared for	a. Government Extension Educational Services, b. Manufacturers, c. Local Dealers
Sales	Supply tractors and related equipment initially, and better and improved replacements over the long pull.	a. Manufacturers b. Local Dealers
	Provide credit so that farmers can purchase equipment. (Eliminate subsidies)	c. Government Credit Agencies
After Sales	Provide spare parts, oils and fuels, and maintenance service during the lifetime of the tractor and equipment	a. Manufacturers b. Local Dealers

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