# THE UTILIZATION OF SMALL TRACTORS IN INTEGRATED AGRICULTURAL DEVELOPMENT: THE TRACTOR EVALUATION PROJECT APPLIED

By

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# THE UTILIZATION OF SMALL TRACTORS IN INTEGRATED AGRICULTURAL DEVELOPMENT: THE TRACTOR EVALUATION PROJECT APPLIED

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## I. Introduction

The American family farm continues to be the bulwark of our agricultural community and is widely regarded as "the most efficient farm plant in the world" (1, p. 10; 2, p. 40). Not only is the well-run, family farm a highly productive operation, but it provides the farm family a standard of living that practically equals the standard of living in the cities of this nation. These facts have fascinated those responsible for planning the agricultural development programs of many so-called less-developed countries. Their problem is to identify the equivalent essential parameters of an "ideal farm" for the particular social, political, agronomic and other conditions of their countries.

Much analysis has presumed that the economic success of the American family farm and the high productivity of American agriculture was associated with the "large size" of the American operations in comparison with the size and productivity of the farms in the developing countries; that is, the advantage is an economy of scale. However, the comparative performance of even larger farms, such as the Russian collective farm, the plantation of the tropics, or the U.S. corporate farm, indicates that the U.S. family farm enjoys a factor of advantage other than the economy of scale. Management by the independent owner-operator stands out as the vital characteristic of the American family farm.

> No other single thread of policy runs through our agricultural history with such consistency--or with such success--as the policy that favors the family farm. (1, p. 6)

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This understanding of the strength of U.S. agriculture has encouraged agricultural planners in the developing countries to increase resources for programs to strengthen the existing owner-operator farms of their nations. Because of population density and limited resources, the typical farm of the developing countries will be smaller than the American counterpart, but for all the developing countries the institution of the family farm is a highly desirable political and social institution.

The governments of the developing countries, particularly the planning ministries or departments, recognize that increased agricultural productivity in terms of unit land area is a prime requirement for national well being. Greater production is needed to feed and clothe the nation and greater productivity is needed to realize the targets of improvement in living standards proposed in the national development plans. A logical course for simultaneously achieving these objectives would be to introduce tools and equipment to raise the productivity of the agricultural enterprise and its workers. However, options in introduction of mechanization are seriously constrained by lack of investment resources and by concern that a mechanization program would aggravate an already serious rural underemployment situation. This study is an investigation of an intermediate technology that would raise farm productivity with minimum capital requirement and minimum labor displacement effects.

This paper describes a process of mechanization by the introduction of small tractors on the small farms of an Indian state, Uttar Pradesh (U.P.) in the Gangetic Plain of North India. This analysis is intended to provide a quantitative insight into the dynamics of the mechanization process; a problem that has been heretofore commonly considered in more general terms.

## II. The Mechanization Alternatives

The selection of the best farm mechanization system is determined primarily by the size of the farming operation, including difficulty of the work to be performed, and secondarily by anticipated ownership and operating costs. In other words, a family farm operation requires a power unit with which the family can complete the seasonal work within the available time period. The penalty for too small a power unit, or unreliable availability, is reduced yields; while the penalty for too large a power unit is excessive depreciation and overhead costs. At this point there is only fragmentary data available to estimate farm machinery functional and economic performance factors for the service conditions of the tropics and the agriculture operations of the developing countries. The following comments on alternative power units contain a large component of subjective judgment by the author.

The most promising alternative systems for increasing power and equipment on small farms are of three types; i.e., 1) improved, bullock-drawn implements with upgraded draft animals; 2) small tractors of less than 15 horsepower selected according to independent farm power requirements; or 3) 35-horsepower conventional tractors utilized by several farm operations either under shared ownership or by hired use. Each of these alternatives has the performance capability to meet the functional requirements of the various tillage, harvesting, processing and maintenance operations of small farms. The three alternatives differ significantly in initial capital cost and potential effective command area under normal management. The information now available indicates that the command area of each power alternative is: improved, bullock-drawn implements are optimally utilized on 2-5 hectare farms; the less than 15-horsepower tractors on farms with a total of 5-20 hectares; and the 35-horsepower tractors on farms totaling above 20 hectares. The level of mechanization is approximately equivalent in each case, that is, the investment level is $50-90 per hectare, the level of power unit use would be 500-700 hours per year, and power cost per unit of harvested crop would range $20-40 per hectare. Local operating conditions, operator skill, farm management practices, and many other factors can cause wide variations in these factors.

The 35-horsepower tractors have been recommended strongly by the farm equipment manufacturers in the developed countries because of the low cost per horsepower and high versatility of these machines. The 35-horsepower tractors have been imported throughout the developing countries and used successfully under practically all soil and crop conditions. Manufacturing of implements and tractors has been established in several of the developing countries. However, the 35-horsepower tractor has been purchased by only the relatively few larger farmers of the developing countries and there has been little success in making the 35-horsepower tractors readily and economically available to the smaller farms. Relatively few tractor owners hire out their tractors largely because of the combination of factors which minimize depreciation in value and generally provide inadequate servicing support. Those few farmers who hire out their equipment are quite cautious in limiting use to family members' neighboring plots, which also facilitates collection for services rendered. At present there is no credit program under which a landless laborer could purchase a tractor as a means of establishing himself in a business as a contractor. In the final analysis, the 35-horsepower tractor is unsatisfactory on two accounts: first, there is no satisfactory management technique (commercial hiring or cooperative) that has successfully provided the small farmer adequate flexibility in access to tractor power according to individual farm needs; and second, the continued promotion of the 35-horsepower tractors contributes to a subtle social and political pressure in support of land consolidation into larger farm operations.

Improved, bullock-drawn implements are also seriously limited in the range over which they have comparative advantage. There have been literally millions of man-hours and vast amounts of money spent on research with unimpressive results. Foster has measured an increase in farm field tillage capacity of 30-100 percent for bullocks using improved implements (3). However, diesel or electric power is required for irrigation and threshing of the high yielding varieties. The farmer may realize some improvement in tillage quality and a saving in tillage time, but his farm plan remains seriously constrained by the limitations of animal power. There are various estimates of replacement animal costs ranging from zero cost to the cost of maintaining seven animals per each work animal. At low population density and low levels of power use animal raising and maintenance can be done on waste and by-product feeds with little apparent cost, but to raise the quality and numbers of bullocks will result in real costs. The calculations of the following sections attempt to reflect the current levels of cash costs. Also, entrepreneurs, both small-scale and large-scale, have unsuccessfully attempted the manufacture and marketing of the more promising implements. In brief, the improved, bullock-drawn implement system offers very limited potential for improvement in raising farm productivity or reducing production costs, and there is little opportunity to improve the relative performance of animal power as agricultural operations become more intensive. However, animal power will remain the best source for the smaller farmer, 2-5 hectares, who places a premium on independent operations, and for all farmers not served by a commercial infrastructure.

Small tractors such as are successfully used on the small farms of Europe and Japan have had wide support as a potential power unit for the small farms of the developing countries. The cost of such tractors can be kept to a minimum by holding horsepower and size below approximately 15 horsepower and thereby eliminating the need for electrical starting systems and implement lifting hydraulic systems. The large number of small farms suggests that mass production techniques could be utilized to further minimize costs. Nonetheless, numerous trials of Japanese and European tractors have not led to manufacturing projects, apparently because of a variety of functional and engineering problems.

In order to systematically study the farm power needs of small farms, confirm the apparent functional utility of small tractors and also systematically study the engineering problems of small tractors and matching implements, the Allahabad Agricultural Institute, (Allahabad, U.P., India), established the Tractor Evaluation Project (TEP). The TEP was a three-year study of the performance of tractors of 5-15 horsepower on farms in the vicinity of Allahabad. The project was supported by a grant from the Ford Foundation and tractors were studied on 29 farms within 25 miles of the Institute. During this project the functional and engineering problems were adequately resolved to permit the farmers to master operating skills in less than a month's time and successfully convert their farming operations from bullock to tractor power while at the same time generally raising their level of production and incomes. The TEP concluded with recommendations of four basic tractors and matching implements suitable for manufacture and sale in India (5). The Project is described briefly on pages 14-19 and the recommended tractor specifications are summarized in Tables 3 and 4. The most significant finding of the project was the demonstration of the role of small tractors in enabling the small farmer to further exploit the potential of the small family farm enterprise.

The major unknown about the small tractors at the outset of the TEP was, would a small tractor completely replace bullocks as a source of farm power. The project discovered that a 5-horsepower walking tractor could pull the same implements as a pair of 1000-pound bullocks, the largest size common in the Allahabad area. However, one man and a walking tractor can work more hours in a day and in addition travel at a moderately faster pace with the same effort, therefore a 5-horsepower tractor can actually replace two pair of bullocks. Indian farmers would naturally prefer to ride on the tractor rather than walk, however it takes approximately five horsepower to carry the man under the usual field conditions of tillage operations. Therefore a 10-horsepower riding tractor is required to replace a 5-horsepower walking tractor, or two pair of bullocks. By and large the farmers readily understood the implications that riding was a luxury and acknowledged that properly adjusted implements and a walking tractor were significantly easier to control than bullocks, thus even the walking tractor was an improvement in working conditions.

The project also demonstrated that farmers had serious difficulty learning to operate 10-horsepower walking tractors, particularly with tillage tools. Unless the tools were properly adjusted they were nearly impossible for the farmer to control, a particularly serious matter for inexperienced farmers who had many problems recognizing the cause and correction for improper adjustment. Once the farmer had mastered the skills of adjusting walking tractor implements (on smaller tractors) it was possible for them to operate the 10-horsepower tractors, although at close to their limit of endurance during the hot weather. For these reasons, the TEP tractor recommendations included two walking tractors, one of 5-horsepower and one of 10-horsepower: the smaller size as the initial replacement of a pair of bullocks and the larger for the farmer interested in increasing his supply of power. The riding tractor of 10-horsepower was included in the recommendations because it used the same implements as the 5-horsepower walking tractor and could be a suitable replacement for a farmer who reached the point that he could afford the luxury of riding. Similarly the 15-horsepower riding tractor uses the same implements as the 10-horsepower walking tractor. These basic specifications offer some opportunity for multiple use of components and some interchangeability of parts which is expected to minimize the costs of the system, allow for better matching of farm needs and power supply, and allow for a minimum cost evolution to higher power levels as farmers felt the need and acquired the capital.

The potential of small tractors is demonstrated more convincingly by comparative cost analysis. The selection of the least cost power unit among the choices of interest in this study must be considered in relation to specific farm requirements for the typical farm sizes and operations of the area. Using partial budget analysis, Kahlon (6), Zachariah (7), Sapre (8), Johl (9) and Singh (10) have shown that tractors, nominally of 35-horsepower rating, are less costly than bullocks for the farms on which tractors are now being used in India. However, these farms are well above average size and therefore represent a relatively small portion of Indian farms. Balis (11) undertook a comprehensive analysis of costs of bullocks, 10-horsepower tractors, 25-horsepower tractors and 50-horsepower tractors under standardized farming conditions. In this analysis the theoretical minimum cost of power per acre for alternative power units was: bullocks, $15.67 per acre; 10-horsepower tractors, $12.53 per acre; 25-horsepower tractors, $9.60 per acre; and 50-horsepower tractors, $9.06 per acre for annual use of 15, 90, 175 and 375 acres of crop cultivation respectively. Balis used crop acres as the standard measurement of comparison; i.e., ten farm acres at a cropping intensity of 130 percent is 13 crop acres per year. This analysis was based upon 150 days per year available for tillage and crop cultivation, a level significantly higher than is now commonly practiced. In drawing conclusions from this study, Balis adjusted recommended control area for each power unit to conform with reasonable boundaries between power options while retaining the relatively high level of use and thus recommended the following applications of farm power (11, p. 37).

| Farm Size (crop acres per year) | Power Source |
|---|---|
| Less than 10 | Hired bullocks or tractors |
| 15 to 40 | 1 to 4 pair of bullocks |
| 40 to 90 | 1 to 2 10-horsepower tractors |
| 90 to 250 | 1 to 2 25-horsepower tractors |
| More than 250 | 50-horsepower tractors |

More recently a Ford Foundation staff paper provided the following recommendations (12, p. 25):

| Farm Size | Power Source |
|---|---|
| Up to 5 acres | Bullocks or hired tractors |
| 5 to 12.5 acres | 4 to 12 tractor horsepower |
| 12.5 to 25 acres | 12 to 25 tractor horsepower |
| 25 to 50 acres | 25 to 40 tractor horsepower |
| 59 acres or more | 40 tractor horsepower or more |

The relative importance of these alternative power sources for the agricultural sector in India is best indicated by the number of farms and area cultivated by the respective group of farms best served by the different power units. Table 1 has been constructed after review of the Balis and Ford Foundation recommendations for power application and using the farm size distribution data of the National Sample Survey of the

Government of India (13, p. 48). According to studies of family farm operations reported by the U.P. Agricultural University, field operations are accomplished with a minimum of permanent hired labor on the farms in the 5 to 25 acre range (14, 15). Farms of 5 to 10 acres are generally controlled adequately and economically by one pair of bullocks. Farms of 25 to 50 acres, although employing permanent labor are herein presumed to be essentially family farm operations and adequately served by a tractor of less than 15 horsepower. Table 1 illustrates that the size range of 10 to 50 acres represents essentially half of India's cultivated farm land and nearly 10 million farms; a very significant segment of the agricultural sector and one adequate to justify the investment in the tools and equipment optimally matched to the needs of these farmers.

TABLE 1. ALL-INDIA FARM POWER SPECTRUM

| Farm Size | Power Source | Farms | | Area |
|---|---|---|---|---|
| | | Number | Percent | |
| (acres) | | (thousands) | | (percent) |
| 0 - 5 | Hired | 31,076 | 62.3 | 19.0 |
| 5 - 10 | Bullocks | 9,646 | 19.3 | 20.3 |
| 10 - 25 | Small Tractors | 6,843 | 13.7 | 30.8 |
| 25 - 50 | Small Tractors | 1,795 | 3.6 | 17.9 |
| 50+ | Large Tractors | 514 | 1.0 | 11.8 |

Thus, the small tractor measured in terms of the small farmer's needs for an economical power source successfully passes the test. For the 10 to 50 acre farms the small tractor is less costly than bullocks. The 35-horsepower tractors can be less expensive only if used over several small farms, a practice that has not proven to be successful. The next stage in the analysis is to study more carefully the implications of small tractor introduction in an extensive program of farm mechanization.

## III. Uttar Pradesh: The Agricultural Context

Uttar Pradesh provides an interesting site for the study of small farm mechanization. The map, Figure 1, indicates the location of the state within the Indian Republic. The location of Allahabad, the site of Allahabad Agricultural Institute and the headquarters for the Tractor Evaluation Project are also indicated on Figure 1.

Figure 1. Map of India

Crop farming in U.P. is managed according to a monsoon weather pattern. The soils are predominantly sandy loam with limited areas ranging from red to black and with some heavy clay. Topography ranges from flat to slightly rolling hills and with wasteland found both in the shallow soil of the hilly tracts and in poorly drained areas of the flatland. Soil type varies considerably within short distances and farmers commonly own several types of soils, as well as both upland and lowland, as a risk spreading practice. Consequently, all farms tend to conform to a common pattern of crop management (16, 17).

Unirrigated cropland is farmed with bullock power at approximately 110 percent crop intensity; i.e., 11 acres of harvested crop per year from 10 acres of land. A typical 10-acre farm with typical limited irrigation will cultivate 3.5 acres of wheat, 3.0 acres of sorghum or millet, 2.0 acres of rice, 1.5 acres of pulses and 2 acres of sugarcane, potato, peanuts or vegetables depending upon soil and water supply (17, p. 69). With adequate irrigation the acreage of wheat, sorghum and cash crops is readily increased to as much as 300 percent for portions of better farms with access to tractor power.

The number of modern machines in the state is relatively small in relation to the number of farms, however, machines are sufficiently common that all farmers have some knowledge about source of supply, cost, availability of repairs, etc. The village-level extension agents have demonstrated and supplied improved, bullock-drawn tillage implements, crop sprayers, crop dusters, and seed drills. More than 50 percent of the farms in the region use one or more improved, bullock implements purchased within the last five years, generally under government subsidy programs. Nearly 20 percent of the land is irrigated and one-half of this is with diesel or electric pumps owned by the farmers for their independent and exclusive use. Sixty percent of the villages have either a diesel or electric mill for grinding wheat flour, polishing rice and cutting fodder. There is a population of 10,700 35-horsepower tractors in the state. Power tillers, imported from Japan, have been demonstrated in U.P., however, few have been purchased. There are perhaps 20,000 power threshers used for wheat. In addition to the blacksmiths found in about one-third of the villages, there are small workshops in the market towns and regional cities which make improved, bullock implements, power threshers, tractor implements, pumps, diesel engines and other farm tools and equipment. There are dealers for six tractor brands, ten pump brands, ten diesel engine brands and a number of other tools and machines produced outside of the state.

Railroads connect the regional cities. Highways connect all market towns and their nearest city. Approximately one-quarter of the villages are not connected to the nearest market town or an adjoining village by an all-weather road. Mail service and telephone service follow the pattern of road service with the quality of service in any location typically related to the accessibility of that location by road.

The market towns are the farmer's usual source of supply for seed, fertilizer, diesel fuel, farm machinery repairs and other purchased supplies. The merchants in the market towns are generally agents or sub-dealers for the manufacturer's franchised agencies located in the regional cities, and often closely related to the farmer's traditional produce marketing agent. As a general rule, farmers would probably use more seed, fertilizer and other inputs if they were available at the right time, but unreliable delivery and uncertain quality inhibit farmers in following intensive farming plans. At the same time, merchants are aware of the erratic delivery of supplies, current low volume of business, comparatively high cost of inventory maintenance, uncertain long-term policy of the government regarding private trade, etc.; all disincentives to investment in improved trading practices. Farmers also find that credit and technical services are no more readily available than are input supplies. Merchants, blacksmiths and traders in the villages are not currently involved in the handling of the newer inputs and may on occasion put up opposition to efforts being made to introduce technology in the local community in part out of conservatism, but more frequently because they perceive the new technology as a threat to their own livelihood.

Throughout the region there is an evidence of development that includes the increased population of bicycles, more transistor radios, the increased number of stores handling agricultural inputs, expansion of grain markets, new small-scale industrial estates, etc. Small-scale manufacturers have taken advantage of free plans, the subsidy programs, and community development promotion to start the manufacture of improved, bullock-drawn implements. There have been many starts, but these bullock implement manufacturers have not gained any financial strength. This is in sharp contrast to the situation for the irrigation pump industry where the official assistance has been limited to partial credit subsidy. Nonetheless, local small-scale units and large-scale competitors are sharing a growing irrigation pump market.

## The Farms

The farms of U.P. are composed of a wide range of operations. The National Sample Survey of India includes anything from 0.01 hectare or larger as a farm operation. Families with land holdings of less than five acres generally supplement farm earnings by off-farm employment either in industry or on neighboring farms. The average U.P. family consists of 2.71 workers (13, p. 50), 160 working days per worker are considered full-time employment, and current farm practices involve 86 labor days per acre per year (15, Appendices) therefore full employment of the average family would require 8.2 acres. By and large, there is considerable exchange of labor among farmers, because of the labor intensive methods used and because of the advantage in intensive inputs at the time when conditions are right. Even the one and two acre farmers hire-in labor during the course of certain critical operations, but then proceed to hire-out themselves or some of the family members when their own field work is completed. Seasonal and local factors alter practices considerably.

Farming in U.P. is classified as animal-powered, however, mechanical sources of power are also utilized. The common draft animals have an average work capability of seven acres of normal cultivation per pair or team under unirrigated or moderately irrigated farming (11). In the opinion of the farmers of U.P., the work load on the farms of less than five acres does not justify the individual ownership of a pair of draft animals, therefore acquiring bullock power by hiring either through payment of cash or in exchange for their own labor. Family farm operations can be divided into four groups:

1) farms of 5-10 acres using one pair of bullocks and normally farmed without permanent hired labor;
2) farms of 10-25 acres using 2, 3 or 4 pair of bullocks who utilize permanent hired labor as well as family labor for field work;
3) farmers who own 25-50 acres, several pair of bullocks, perhaps a tractor and who generally hire labor for field work but supervise field work closely; and
4) owners of more than 50 acres who may own a tractor in addition to one or more pair of bullocks and frequently entrust all farm operations to a hired manager.

As farmers shift to intensive irrigation and multiple cropping they either increase the number of bullocks, increase the size of draft animals used, or turn to tractor power as a supplement to bullock power in completing the additional work load.

The farm size distribution pattern for U.P. is essentially the same as the all-India pattern. The estimated number of farms and percentages of total farms and total area in the power-size groups are shown in Table 2. The importance of the 10-50 acre farms is demonstrated by the fact that they control 50 percent of the cultivated land in the state. Any program with this group alone would be a major operation involving 1.5 million farmers and 21.7 million acres.

TABLE 2. U.P. FARM POWER SPECTRUM

| Farm Size | Power Source | Farms | | Area |
|---|---|---|---|---|
| | | Number | Percent | |
| (acres) | | (thousands) | | (percent) |
| 0 - 5 | Hired | 5,179 | 62 | 19 |
| 5 - 10 | Bullocks | 1,607 | 19 | 20 |
| 10 - 25 | Small Tractors | 1,140 | 14 | 31 |
| 25 - 50 | Small Tractors | 299 | 4 | 18 |
| 50+ | 35-horsepower Tractors | 86 | 1 | 12 |

In summary, U.P. farms are relatively uniform in their characteristics. Farming operations are diversified food grain cultivation. Farmers are just adapting the use of purchased inputs, although limited somewhat by irregular supplies. Farm power is a production constraint and innovations are sufficiently common that most farmers have some knowledge of machinery and its characteristics. From the point of view of introducing small tractors in U.P., such factors as the uniformity of farms, the demonstrated potential to utilize high yield technology, the existence of machinery manufacturing and servicing facilities, and the relatively large potential market are assets. While problems should be anticipated, the overall situation is potentially favorable to mechanization of the 10-50 acre farms using tractors of less than 15 horsepower.

The Farmer

As an independent farm manager, the farmer is a key decision maker in the transition to tractor power from bullock power. Very little data is available on farm decision making for the Indian farmer. Several recent studies on farm management of fertilizer (18), seeds (19), irrigation practices (20), and general agricultural modernization (9), report that the farmer makes economically rational desisions and has a generally progressive attitude intending to raise his farm production and personal income. At the same time the farmer is seriously constrained by limited local availability of input supplies and often hampered by insufficient credit. The typical progressive farmer has a third-grade education, maintains some records of farm production and generally is familiar with modern inputs availability and input cost from more than one source of supply (15).

The farms of 10-50 acres, which are of primary interest as potential small tractor farms, presently employ one or more permanent laborers. These laborers are normally responsible for the driving of the bullocks and their care and feeding. Particularly on the smaller farms, the farmer is also a bullock driver and therefore is required to work in his field at the very time when the supplies of seed, fertilizer, etc. can be most readily found in the shops. The farmer does not visualize the input supply system improving and therefore considers the use of a tractor by his hired hand as a necessity to enable him as farm owner-manager to acquire additional input quantities along with the improvement of the necessary field operations. It has commonly been observed that the farmer's intention is to retain the services of his permanent labor and arrange for his training as a tractor operator. The farmer would then use his time as a manager in arranging for more fertilizer, better seed and other inputs for intensification of his farm operations. This intention reflects the farmer's traditional value system where status is acquired by limiting oneself to management functions, as well as also reflects the farmer's expectation that he can make more effective use of his land and the additional power by also increasing input use to raise farm productivity and thereby support himself and his labor. Owners of larger tractors have consistently raised labor employment after conversion to tractor power (9, 10).

A serious concern regarding farm mechanization is the relatively low level of formal education and seriously limited mechanical skills of the rural people. The owners of 10 to 50 acres will generally have somewhat above average school attendance, perhaps 3-5 grade, but this level would not be adequate for them to acquire tractor and equipment service skills simply by reading conventional operator's instruction manuals. Owners of 35-horsepower tractors have acquired operating skills by hiring a trained operator for a period of a year or two and this practice could be followed by the farmers in the 25-50-acre range. Manufacturers have also conducted service and operators training sessions for new owners and this technique has considerable potential for more effective application. Some mechanical talent exists in rural villages and successfully maintains irrigation pumps, wheat grinding mills, and other simple machines, however, maintenance is not consistently at a high level and is not adequate for small tractors. A number of these service points are operated by mechanics trained in the schools provided by the 35-horsepower tractor manufacturers, or mechanics returned to their home village after work in urban industry or in the army, which demonstrates a potential to develop mechanical skills in rural villages. The situation does not appear to be a lack of aptitude, but simply a result of the present low level of investment in education and technical training.

In summary, the current farmer attitudes and values are compatible with a conversion from bullock power to tractor power. The farmer's shrewd insight is particularly evident in his perception that the shift to tractor power must be concurrent with a shift in farm management to more intensive multiple cropping and greater use of the high yielding technology. Further, the farmer's recognition that the higher levels of farm production will place greater demands upon his time is also evidence of sound judgment and a rational attitude regarding mechanization. Of course, the enthusiasm of most 10-50 acre farmers for undertaking the bold step of mechanization is tempered, almost to the point that interest is only a faint glimmer, by his own recognition of the transitory problems such as learning tractor operating skills, arranging credit for this kind of purchase, arranging for service and repairs, arranging more farm inputs, and successfully marketing more outputs.

For the total agricultural context of U.P., the situation can be considered one where mechanization of the small family farms is possible. although there are a number of factors that will inhibit the transition. Farmers have begun a transition to high yielding technology and universally intend to raise the productivity of their enterprises. From an agronomic point of view, adequate potential exists in the soils and climate of U.P. Infrastructure is developing, although lagging the demands placed upon it by the agricultural sector. In this context, the establishment of a small tractor mechanization program must provide for nearly all of the infrastructure needs as well as the manufacturing plant and equipment. The fact that farmers express the intention of raising farm productivity in the course of the transition suggests that there will be urban and social benefits also from the farm mechanization program. In order to determine the quantitative dimensions of the mechanization process the tractor performance and farm operating data of the Tractor Evaluation Project is used as the basis for the following analysis.

## IV. The Tractor Evaluation Project

The Tractor Evaluation Project (TEP) was undertaken to measure performance characteristics, identify critical design parameters, and study farmer reactions in the application of small tractors in Indian agriculture. This project was a component of the Agricultural Engineering research program at Allahabad Agricultural Institute. The TEP was undertaken with a grant from the Ford Foundation. The project staff consisted of six Indian Agricultural Engineers and three Peace Corp Volunteers with the author as senior engineer in the project. Field work extended through the 1964-65 to the 1966-67 crop seasons. Tractors were placed on 29 cooperating farms and performance data was also collected from the Institute farm and engineering research program. An objective in the study was to rapidly provide quantitative data on tractor performance and identify critical engineering problems. Excess staff capability was provided to ensure maximum field operation and the staff time not required in farmer assistance or performance measurement was spent in engineering analysis of equipment adaptation. It was initially visualized that the TEP would be extended at the end of the first three-year phase and revised as appropriate to concentrate attention as suggested by the initial field operations. However, because of a combination of extenuating circumstances, the project was terminated in early 1967. Nonetheless, the TEP data provides considerable evidence to support the introduction of small tractors on the small farms typical of the Allahabad region.

The TEP provides performance data for tractors of less than 15 horsepower on 10 to 50 acre farms of eastern U.P. In the TEP, walking and riding tractors with complete sets of implements were purchased in Japan, Germany, Switzerland, U.S. and India. Prior to placement of the tractors, the farmers were trained in the proper use of the tractors and implements. Throughout the project the farmers were given technical support in making maximum use of their assigned equipment. During the course of the study the use of the machines was systematically recorded and studied. The final report of the project recommended design features of small tractors for introduction in Indian agriculture.

The TEP was organized as an on-the-farm study of small tractor performance. Measurements of performance were carefully undertaken, but not under sufficiently controlled conditions as to be a reproducible engineering test of tractor performance. To a considerable extent the project was organized similar to the preproduction field trial program commonly followed in the design and development of a new tractor line. In planning the TEP it was assumed that the imported tractors and implements, with minor adaptation, could meet the farmers functional requirements and provide an indication of the performance, costs, design parameters, and infrastructure requirements for farm mechanization. This data was considered as a preliminary study to further investment in research and development of an indigenous small tractor.

The use of imported equipment minimized the costs and time of designing and building the equipment. The tractors and implements were selected in terms of expected utility for the common agricultural operations of the project area. The project staff undertook limited equipment modification to improve suitability and performance, although this was a secondary aspect of the project. The rapid acceptance of tractor power and the extensive use of the equipment attests to the functional suitability of the equipment.

The farmers were selected from among the progressive farmers recommended by the Block Development Officers. These men were cultivating high yielding varieties and a portion of their farm was irrigated land. During the first interview the objectives of the project were explained and information was collected about the farmer, but he was not asked at that time to accept or reject the use of the tractor. After consideration of a number of the nominees of the BDO, a few farmers were interviewed a second time, and sometimes a third time, before they were accepted as representative farmers and given an opportunity to cooperate in the project. Their cooperation required a willingness to learn tractor driving and to keep the records of tractor use required in the TEP. They further agreed to purchase all fuel and lubricants required and follow the routine tractor service procedures recommended by the tractor manufacturers. The farmers were not charged rental for the use of the tractors under the expectation that they would maintain their bullocks during the term of the project. The farms accepted the fact that a longer term arrangement was not possible until the utility of the tractors was proven by the project, but that once the results were known there was a possibility of Indian manufacture of equipment similar to the "best" units as identified in the course of the field work.

The project staff was equipped to support the tractors in simulation of the service infrastructure that would be available under a well established tractor industry. The farms were visited frequently, as there existed no other means of the farmer reporting difficulties. During the course of such visits the engineers recorded the field operating rate for the operations under way and made other observations of performance. If repairs could not be made in the field, the equipment was hauled to the headquarters, repaired and returned to the farmer within two days.

The cooperating farmer experimented considerably with tillage operations before reaching an optimum which provided both minimum cost and an apparently "high quality" job. Among the project equipment a wide variety of choice was open to them; including several kinds of plows, several kinds of rotary tillers, disk harrows, field cultivators, drags, rollers, etc. Because bullocks are relatively slow, the farmers had traditionally started tillage well in advance of planting, and they initiated tractor tillage about the same dates at the beginning of the project. However as they also completed their first tillage operations quickly they often undertook second, third or more tillage operations to do a "better" job. Here again they initially followed precedent which encouraged as many tillage operations as were possible between the start of the tillage season and the time of planting. However, when they used tractor tillage they improved the "tilth" of the soil relatively little by the subsequent operations and in addition to the extra cost actually caused unnecessary moisture loss. While the project staff made every effort to advise the farmer, there was no attempt made to restrict these experiments. By and large, no farmer conducted such experiments to the extent of incurring serious loss. This process of experimentation verified the initial recommendations of the project staff regarding tillage; for the least possible travel across the field and generally required only two trips--a deep primary operation and a secondary finishing operation according to crop and season.

Upon mastery of the technique of good tillage the farmers were called upon by their neighbors for hiring out. Hiring was routinely discouraged by the project staff in the interest of ensuring that the farmer used the tractors to complete all operations on their own farms. Actually most farmers were able to easily complete their own work in a timely manner and also realize a sizable income from hiring. This total use, on-farm plus hired-out, further substantiated the estimation of potential tractor control area at the levels of 1.5 to 5 acres per horsepower.

In addition to tillage, hauling or cartage was the most common hiring operation for some cooperators, and others found that irrigation pumping was more in demand. This demand depended upon both the local needs and the preference of the cooperator in undertaking the work. If they liked to travel they could find plenty of haulage and at a price that was adequate to cover the costs, and also competitive with either bullocks or trucks. The demand for tractor irrigation was high where there was no electricity and wells were shallow or ponds were numerous. The mobility of the tractor pump made it a very popular combination in some cases. Although the cooperating farmers had heavy demand for hiring, most of their customers proved to be adequately large farmers to be potential tractor owners. Consequently, hiring does not appear to be a particularly prominent aspect of small tractor use in the longer term analysis.

The project operations made a number of compensations for the limited infrastructure and tractor service facilities. These were adequate at least to the extent that tractor use reached the levels of 500 hours per year, but all tractors lost potential work hours because of inadequate supporting services. A significant amount of the farmer's time was spent in travel to obtain fuel, however, this is not considered a serious matter because either wider dispersal of fuel pumps or even village fuel storage can be set up at relatively low cost. Because the tractor failures held valuable engineering information, the farmers were not permitted to make or arrange local repairs. In fact at the beginning of the project it was assumed that they would not be able either to make repairs themselves or find any local repair facility. During the course of the project the farmer demonstrated considerable mechanical competence and also a mechanic of some training, often a retiree from the army, was found within walking distance of every tractor. These men did not have proper tools and generally did not understand the details of the particular make and model, but they had a sufficient understanding of the basics to diagnose accurately more than 50 percent of the mechanical troubles. It would seem that with a minimum of training, and some tools, good service could be provided even to remote areas. However, an additional component of a service program is ready access to the needed repair parts, and the limited transportation and communications facilities connecting most villages will make this a serious problem. Certainly it would be impractical to stock every village with a complete range of repair parts. It is presumed however that supporting infrastructure can be set up at a reasonable cost to permit tractor use at levels higher than realized in the TEP.

The project staff trained the farm owner-operator as the tractor operator, but in every case the farmer was encouraged to train others if he chose to do so. In all cases one or more operators were trained by the farmer, although often only in the technique of driving. In several cases the owner-operator trained and relied heavily upon a long-time hired servant for all tractor operations and devoted increasing attention to more inputs and better management. Even in those cases where the farm owner chose to operate the tractor extensively, he realized more free time during traditional cultivating seasons and utilized this time to intensify his operations, particularly by getting more fertilizer. The farmers demonstrated a very pragmatic attitude in the use of their time and their opportunities as farm managers. In two cases farmers also used their tractors to by-pass traditional middlemen; marketed their produce directly in the city by hauling it themselves, and further increasing farm profits. There was no discernible desire by the farmers to acquire the tractor so that they could reduce either permanent or hired labor, in fact, they demonstrated considerable loyalty toward labor and actually increased their use of hired labor.

In the TEP farmers acquired acceptable operating skills from a three-day intensive program followed by daily visits by the trainer during the first week of on-the-farm use and with continued visits at one week to one month intervals for the next three months to one year. This kind of training program would cost an estimated $250 per farmer for the first tractors in a region. As the tractor population increases the techniques of tractor operation can be learned from neighboring farmers, and follow-up training could be combined with neighborhood service calls. The actual cost of training operators in a mechanization program will depend greatly on both the density and rate of mechanization along with the complexity of the equipment.

The measurement of farm performance was a secondary objective of TEP and therefore less detailed than those of tractor performance. Farmers consistently increase multiple cropping acreage either by taking advantage of more rapid tillage to plant the additional land or by using the tractor for the needed extra irrigation. Crop yields prior to tractor use were not measured, except insofar as the farmers kept their own records. All farmers claimed higher yields under tractor cultivation, and their neighbors concurred. However, the greater yield may have been the result in part of better seed, more fertilizer, or better management that was commonly combined with tractor use. The farmers made adjustments in farm management with each planting season, and each farmer followed essentially a unique management approach. Consequently, although the farmers had a strong opinion that tractor use enabled higher yields, the obvious result was the steady increase in multiple cropping. For the project farmers, the cropping intensity was raised from 110-130 percent range with bullock power to 150 percent within a period as short as one year and for all farmers within three years. The farmers had developed plans to raise intensity to 200 percent or more by the fifth year of tractor use and a number of farmers had rational plans to raise intensity above the 200 percent level.

The results of the project were judged favorably on several accounts. The farmers, after two to six months, sold their bullocks and relied entirely on the tractors. The total hours of use, even for the first year, reached more than 500 hours, which is generally considered a good level of use by U.S., Japanese and European agricultural engineers. In nearly all cases the farmers indicated their willingness to purchase the tractors and implements at the end of the project, however, the Institute chose not to sell the equipment as there was no long-term arrangement for import of repair and service parts. Several Indian manufacturers have utilized the project reports in pursuing research and development programs for indigenous manufacture of small tractors. The limited research of the TEP indicated that tractor use could be doubled in a three to five year period.

The final report of the TEP summarized the performance expectations for small tractors as shown in Table 3. The project recommended basic design parameters for small tractors as shown in Table 4. Also, complete evaluation reports were prepared for each of the tractors included in the TEP. These reports include a summary of the operating performance on each farm, comments on implement design and adaptation, summary and analysis of failures, and comments on the suitability of the tractor and its implements as a prototype for Indian manufacture.

The TEP reported that approximately 3.5 to 5 acres can be controlled per tractor horsepower at the 110 percent crop intensity. During the course of the project the cooperating farmers quickly took advantage of the possession of the tractor and increased the crop intensity to 200 percent and correspondingly reduced the command area of the tractors to two to four acres per tractor horsepower. For comparison, farmers owning 35-horsepower tractors may own as little as one acre per horsepower, although the more common ratio is two to three acres per horsepower.

TABLE 3. SMALL TRACTOR PERFORMANCE SUMMARY TABLE*

| Years of tractor use | 1 - 3 | 3 - 5 | 5 - 10 |
|---|---|---|---|
| Land area controlled (A/Hp) | 4 | 4 | 3 |
| Cropping intensity (percent) | 150 | 200 | 225 |
| Irrigation pumping (hours) | 200 | 250 | 300 |
| Tillage (hours) | 125 | 175 | 225 |
| Carting[a/] (hours) | 50 | 50 | 50 |
| Seeding (hours) | - | 50 | 150 |
| Threshing (hours) | - | 25 | 100 |
| Spraying (hours) | - | 25 | 50 |
| Miscellaneous (hours) | - | 25 | 25 |
| Hired out (hours) | 100 | 100 | - |
| TOTAL HOURS | 500 | 700 | 900 |

* John S. Balis, Progress Report No. 14--Summary of the Project, The Tractor Evaluation Project, Allahabad Agricultural Institute, March 1967.

a/ Does not include travel to market or near villages for family, social or similar purposes.

TABLE 4. RECOMMENDED TRACTOR SPECIFICATIONS*

| | I | II | III | IV |
|---|---|---|---|---|
| Tractor Style | Walking | Walking | Riding | Riding |
| Engine Horsepower | 5 | 10 | 10 | 15 |
| Weight (lbs.) | 325 | 650 | 1,000 | 1,500 |
| Drive Wheel Size | 4 X 10 | 650 X 16 | 6 X 16 | 8 X 24 |
| Wheel Tread Min. (in.) | 14 | 24 | 32 | 37 |
| Wheel Tread Max. (in.) | 24 | 36 | 36 | 48 |
| Clearance (in.) | 6 | 8 | 10 | 16 |
| Wheelbase (in.) | - | - | 48 | 60 |
| Front Wheel Size (in.) | - | - | 4 X 10 | 4 X 10 |
| Turning Radius (in.) | - | - | 66 | 84 |

* Source: Progress Report No. 5--Recommendations of Specifications for Tractors of Less Than 15 Horsepower Which are to be Used in India, Tractor Evaluation Project, Allahabad Agricultural Institute, October 1966.

In summary, the TEP demonstrated the utility of tractors of less than 15 horsepower on the 10-50 acre farms of U.P. This project established certain tractor performance parameters. However, the aggregate effects of extensive use were not measured. The following sections combine the performance data of the TEP for small tractors with the available information on high yielding agricultural technology and with the current performance data for Indian industry to construct an analysis of the impact of farm mechanization on the economy of U.P.

## V. Application to Uttar Pradesh

The introduction of 5-15 horsepower tractors in U.P. would require the establishment of manufacturing, distribution and servicing facilities, in addition to expansion of the infrastructure servicing agriculture in input supply and commodity marketing. Considerable speculation is involved in projecting the employment, investment, credit, and other impacts of a mechanization program because the basic industrial and commercial data resources are very limited. The following analysis must be interpreted with due regard for the limitations of the available basic data, nonetheless the indications of positive benefit from mechanization establishes a case for further investigation and preliminary investments in this sector of development.

The total number of farms in the 10-50 acre range for the state of U.P. is 1,439,000. In the absence of a market survey or other data on farmer attitudes and opinions the following calculations assume that 50 percent will be mechanized in ten years. This rate of adoption, five percent per year, is considerably slower than the acceptance of the high yielding wheat varieties, yet may be an optimistic projection of what is possible. The use of a ten-year target, is intended to equal the life span of the tractors, thus the production capacity established for building up the tractor population would be maintained for production of the replacements needed to maintain the population. Here also bold assumptions about tractor life, rate of adoption and production startup are required, however, the expected deviation of a slower startup sequence will allow adequate time for revision of the program. The assumptions are intended to indicate the impacts of a major program and have been intentionally chosen to display the likely high level of impact. These assumptions then result in a target tractor population of 720,000 tractors and an annual production capacity of 75,000 tractors per year.

This mechanization program could be supplied by as many as 15 small or medium scale tractor production plants plus related implement production and equipment servicing stations. According to the <u>1974 Red Book</u> of the U.S. farm equipment industry there were 131 models of small tractors offered on the market (<u>22</u>, pp. A-67—A-75). The total sales of small tractors reported by <u>Implement and Tractor</u> were 540,136 (<u>23</u>, p. 20). Thus, the U.S. industry is organized with an average production of 4,122 tractors per model per year. Using 5,000 tractors per year as a design level in order to achieve further economy of scale and reduced production costs would allow for 15 production units. The production units could be widely dispersed throughout the tractor use areas and production designs of individual units could be modified to incorporate features meeting local requirements. As yet the author has not explored the question of product mix among the four basic models, but it might be that there would be seven units producing 5-horsepower tractors, five units producing 10-horsepower tractors and three units producing 15-horsepower tractors. The following calculations are simplified, however, by assuming that all tractors are of 10 horsepower.

Selling prices of small tractors on the world market vary widely according to the basic design and the various items or features of equipment included in the tractor price. Current U.S. farm tractor prices average $85 per horsepower; this includes complete electrical systems and implement-lift hydraulic systems (23, p. 30). The prices for U.S. estate tractor may be as high as $150 per horsepower, but this includes automatic transmission and luxury fittings. A small tractor of less than 15-horsepower designed for agricultural use in a developing country could be produced without either electrical starting system or implement-lift system thereby reducing tractor costs to less than $100 per horsepower. Indian selling prices for complete irrigation pump systems run $90 per horsepower and the few small tractors are about $130 per horsepower with tillage tools. The following analysis assumes a selling price of $1500 for a 10-horsepower tractor and the basic minimum implements.

## The Farmer's Costs and Benefits

The cooperating farmers in the TEP raised farming intensity from 110-130 percent to 150 percent within their first year of tractor use and were rather consistent in projecting a cropping intensity of more than 200 percent by their fifth year of tractor use. This expectation of quickly raising farming intensity has been observed in other studies of farm mechanization (8, 9, 10). Some farmers can readily describe how they would proceed to increase cropping intensity to more than 200 percent, assuming the availability of inputs and markets. Considerable research has been conducted to support multiple cropping to the levels of 400 percent (20). In the calculations of Appendix 1 it is assumed that the tractor owning farmers increase cropping intensity from 120 to 175 percent by increasing their rice acreage 100 percent, wheat acreage 50 percent, and cash crop acreage 75 percent. The increase in production due to the greater acreage, more inputs and better management may produce as much as a 400 percent increase in rice marketings, 300 percent increase in wheat marketings and a 75 percent increase in marketings of cash crops. The effects on the farmers production would be a 25-30 percent increase, or an average annual increase of more than five percent--approximately the current target in Indian plans.

The U.P. Agricultural University studies current farm management among small farmers and determined average net income of $45 per crop acre for the upper levels of viability among small farmers (15, p. B-9). Thus, a 25-acre farmer who raises cropping intensity from 120 to 150 percent, the increase observed in one year in the TEP, will add 7.5 crop acres to production and $337 to net income. Gains in yield contributed by the tractor use or gain in profitability for the additional acres may further improve the net income for individual farmers. The additional net income per year would be raised further in subsequent years as cropping intensity is increased to 200 percent where additional net income of $1012 per year may be realized. At this level the entire purchase price of the tractor would be returned in one year's farming operations.

An alternate analysis using comparative power costs indicates 10-horsepower tractor power at a saving of $3.20 per crop acre per year less than bullock power costs (11). The savings for a 25-acre farmer at 150 percent cropping intensity would be $120 per year; a borderline but perhaps adequate level for retiring a tractor loan. A third analytical technique would be to calculate the net income on additional farm marketings. In Appendix 1 the data of the U.P. study (15, p. B-4, B-5, B-6, B-19, and B-20) have been used to estimate the additional net income at $1240 for the 150 percent farming intensity.

A further benefit of a more speculative nature is the possibility for crop and farm enterprise diversification. The sustained growth in cereal grain production for an extensive area such as U.P. would ultimately result in more favorable prices for livestock enterprises. A sustained improvement in urban incomes and continuing rise in expectations will increase the demand for livestock products as the demand for cereal food grains is satisfied. Whether the 10-50 acre farmer establishes a livestock enterprise or other farmers do, the expanded cereal market will benefit the 10-50 acre farmer.

The U.P. farm management study indicates that the 10-50 acre farmer has a farm investment of $30-50 per acre and these farmers are utilizing credit at $10-30 per acre (14, pp. 165 and 169). Thus a 25-acre farmer has an investment of as much as $1250 in his farm and has the credit rating under present rules to make an investment of $750. As a matter of perspective, farmers are commonly investing $100-150 per acre in irrigation pumps and water control systems in comparison with the possible tractor investment estimated in the range of $20-50 per acre. Thus, it seems reasonable to expect the financial institutions to adjust terms and conditions that would permit borrowing for small tractor purchase.

The TEP demonstrated the farmers ability to master operating and servicing skills, arrange housing for equipment, arrange transportation between the village farmstead and the various fields, and generally manage the reasonable application of tractor power. None of the problems encountered in these aspects were insurmountable, although there are many physical features that could be modified to realize improved performance of tractors. For quick mastery and effective application of tractors, farmers will require a training program to learn operating and service skills, which for the first farmers in a community may cost $250 per tractor but proportionately less as farmers are able to acquire such skills easily from neighbors in their home village. In the case of 35-horsepower tractors, new owners have rather limited opportunities to learn operating and service skills, yet this has not been a hindrance to sales. The 35-horsepower tractors have been purchased by the larger farmers who have the resources with which to hire experienced operators or who have the free time to travel and obtain training from one of the few schools. The 10-50 acre farmer cannot as easily use either of these methods. As training will be a major expense, and not included in normal practice for tractor price calculations, manufacturers and the government should give consideration to the manner in which such training will be conducted and financed. Good training programs will improve the benefits that can be realized from tractor application to the 10-50 acre farms.

From the farmer's point of view the question of risk or loss is not a serious concern in respect to tractor ownership. The primary reason is that the farmer perceives tractor ownership as an opportunity to raise farming intensity from its present constraint. In addition tractor ownership in itself represents a gain in status which forestalls any need for immediate large financial gain. With these attitudes regarding risk, and with high returns from increased cropping intensity as potential gain, the tractor investment has a high regard as a sound investment.

In summary, the available data indicate that farm net income for a 25-acre farmer purchasing a small tractor and successfully raising cropping intensity to 150 percent would increase from $300 to $1200 per year. This confirms the rational judgment of the farmer and does not include either effects of yield improvement or increase in per acre rates of return from tractor use, both of which are expected to further improve net income. Proportionate rates of return are expected for all farms in the 10-50 acre range by matching tractor size to farm size in the ratio of 2.5 to 4 acres per horsepower. Such investments in power and equipment can be accommodated with minor modification of present medium-term lending.

Manufacturing and Servicing

It appears that a small tractor and implement manufacturing industry for U.P. could be organized along the same general pattern as that found in both the U.S. and Japan for manufacturing of small tractors; that is, as a joint enterprise of small-scale and large-scale units. A minor portion of the total investment would be in the large-scale sector for the production of standardized components such as engines, transmission and alloy-steel soil-working tools where mass production techniques and economy of scale would provide significant benefits. Production of many tractor components and frames, implements frames and final assembly can be decentralized, labor intensive, small-scale operations which would have the advantage of industrial dispersal and a high level of accommodation to local circumstances and opportunities. The relatively high level of decentralized manufacture has further advantages such as reduction of the length of parts and service "pipelines," interesting investment for rural investors, a reduction in urban migration pressures, etc. The one serious disadvantage to this type of industrial structure is the complexity of coordinated establishment and start-up to reduce costs and time in reaching a satisfactory economic volume.

An analysis of the costs of small tractor manufacturing and servicing in U.P. requires a number of assumptions. The North American farm equipment industry currently places the manufacturing cost at 51-57 percent of suggested retail price; wholesale and distribution costs are 15-20 percent of suggested retail price; and the dealers margin are recommended at 25 percent of the suggested retail price (dealers are commonly selling at 15 percent under suggested retail price and thus realizing only 10 percent of suggested retail price) (21, p. 31). In this case the recommended price breakdown will be utilized to provide the dealers with a larger margin for handling the service needs under the comparatively less well developed infrastructure of rural U.P. The breakdown of manufacturing between large-scale and small-scale industry is arbitrarily established at 45 percent of the cost of manufactured tractors and implements. These calculations are also based on an average tractor of 10-horsepower and value of tractor plus implements of $1500 per tractor. The manufacturing plant and servicing industry is to be designed to produce 75,000 tractors per year, plus five percent for replacement parts and repairs. Thus the total value of annual sales would be $120 million. Of this business $66 million would be manufacturing of which $26.4 million would be supplied by large-scale units and $39.6 million would be the contribution of the small-scale manufacturing sector.

The performance data of U.P. industry may be utilized to construct an estimate of the industrial investment (16, pp. 275 and 280). These calculations are summarized:

| | Large-Scale a/ | Small-Scale b/ | Total |
|---|---|---|---|
| Ex-Factory Sales c/ | $26.4 | $39.6 | $66.0 |
| Investment c/ | $ 8.7 | $17.5 | $26.2 |
| Employment | 4,850 | 31,800 | 36,650 |

a/ Engines, etc.; see Appendix 2. b/ Assembly; see Appendix 3. c/ Millions.

The current performance data for the durable consumer goods service industry involves an markedly different level of performance than is expected for the small tractor industry. The present data show value added of $0.8 million for annual sales of $3.3 million or a value added ratio of 24 percent of total sales. The expected ratio for the North American farm equipment industry is 45 percent, reflecting in part a higher component of services involved in each sale. Therefore, current Indian industrial parameters are doubled for purpose of estimating the industrial parameters for the tractor and implement distribution sector. This provides the following description of the sector:

| | Tractor Servicing[a/] |
|---|---|
| Annual Sales | $120 million |
| Value Added | $ 60 million |
| Investment | $19.2 million |
| Employment | 288,000 |

a/ See Appendix 4.

The total investment in manufacturing and servicing the tractors and implements would be $45.4 million and the total industrial employment would be 324,650 direct salary and wages employees. The size of this tractor industry is particularly noteworthy in relation to the total projected 1975 employment in the U.P. small-scale sector of 165,000. The tractor industry alone would have the potential to more than double that level of employment. Further, the fact that this industry can be established largely in small-scale units has a high potential for attracting agricultural savings for a significant, if not major, portion of the investment required. Also, this industry has a high potential for satisfactory performance under wide dispersal in small units, a further advantage in mobilizing rural resources. Assuming that three-fourths of the distribution investment and half of the small-scale manufacturing investment can be mobilized outside of institutional finance, the net planned investment would total only $22.5 million.

The industrial investment returns in this method of calculation are equivalent to any other investment in the manufacturing industry. Inasmuch as Indian industrial investment is mobilized by official decision and issuance of licenses, a competitive rate of return is not the prime consideration in investment decisions. Potential large-scale investors are expected to be attracted to engine and component manufacturing primarily because of the comparative simplicity of marketing their production in volume and long-term contractural sales to small-scale tractor manufacturers. At the same time the investment in tractor manufacturing and implement manufacturing is expected to be an attractive and productive investment for rural entrepreneurs interested in diversification of their enterprises yet retaining their investments within their local community. Thus, the benefit is not perceived in the high rate of return, but primarily in the possibility of establishing a high capacity and sound industry with a minimum of institutional and large-scale investment.

General Benefits

From the government point of view the basic question is, does farm mechanization of the 10-50 acre farms contribute to the desired social, political and economic goals of the country, and to what extent. These kinds of benefits are difficult to quantify. To a certain extent affirmative answers have already been given in the course of the discussion above. However, additional and more direct benefits also accrue to the government sector. The tractor manufacturing and service industry increased the tax base of the country and to the amount that this industry is built out of agricultural and rural savings, a taxable asset is created out of otherwise untaxed resources. An estimated 50 percent of the investment in the small-scale manufacturing and servicing is expected to be made by such sources, thereby adding $24 million of otherwise untaxed assets.

Introduction of tractors also offers the government a device for channelling rural savings into productive farm investments rather than consumptive expenditures. For example, the investment in a tractor compared with an elaborate marriage ceremony, and these two expenditures are of the same magnitude, expands the productive capacity of the farm as well as channels the expenditure into taxable transactions. Fortunately, the former can achieve social status from tractor ownership to essentially the same degree as through "putting on" an elaborate marriage. Admittedly marriage ceremonies and expenses will not be replaced altogether because of tractor ownership, but that portion of the marriage cost associated with "buying" of status can be diverted from the marriage to tractors. And beyond this the government can also realize greater income as a result of the general stimulation of business activity that will result from the higher farm productivity anticipated. A crude order of magnitude estimate of the additional revenue, based upon a two percent sales tax on tractors and equipment as well as an additional food grain sales, indicates that the additional revenue to the government from U.P. would be $5 million annually.

Perhaps the most critical concern about farm mechanization is the possibility of an adverse impact on farm employment. Small tractors are expected to have a small impact on rural employment, but at the same time have a greater job creating effect in industry and in the food marketing and trading sectors of the economy. By and large the 10-50 acre farmers are not the major employers of daily wage laborers and do not intend to replace their permanent laborers upon procurement of a tractor. The projected manufacturing schedule is expected to mechanize only 50 percent of the 10-50 acre farms, 720,000, and for purposes of estimation of the employment impact the introduction of tractors is expected to displace 360,000 agricultural workers. On the other hand, employment is expected to be increased in the urban sector by a combination of the 50 percent increase in food grain marketings, the increased volume of inputs required, and also by the general increase in consumer goods industries which benefit from the expansion of the economy. The increase in employment is arbitrarily estimated at 20 percent in the trade and commerce sector, 10 percent in the transport and storage sector and 5 percent in other services. The current employment data for U.P. is adjusted accordingly in the construction of Table 5 (16, p. 238). The total impact on employment in U.P. resulting from a small tractor mechanization program is a net increase in jobs of 247,000. This analysis does not include new industries and minor service categories such as office messengers and household servants which, if anything, will also realize a modest benefit from the general improvement in economic activity.

TABLE 5. EMPLOYMENT OF U.P. WITH THE IMPACT OF FARM MECHANIZATION
(thousands)

| | Present Employment | After Mechanization |
|---|---|---|
| Cultivators | 18,428 | 18,428 |
| Agricultural Laborers | 3,261 | 2,901 |
| Trade and Commerce | 1,063 | 1,169 |
| Transport, Storage and Communication | 399 | 439 |
| Other Services | 2,710 | 2,846 |
| Household Industries | 1,474 | 1,474 |
| Other Industries | 1,515 | 1,515 |
| Tractor Industry | - | 325 |
| TOTAL Workers | 28,850 | 29,097 |

## VI. Net Appraisal and Summary

The main benefits to the introduction of small tractors is an increase of food production and the establishment of a new industry. The cost is the displacement of labor from the agricultural labor class to urban jobs in food and other trade plus tractor manufacturing and servicing. The estimates indicate that more urban jobs are created than displaced in agriculture with the result that total employment is increased in line with the new level of food production thus achieving a relative stability in food supply and demand.

### Food Production

For U.P. the introduction of small tractors has the potential to expand food production capability at the rate of 10 percent per year through a ten-year period as the present power constraint on agricultural enterprises is removed from the 10-50 acre farms. With the removal of the power constraint other input supplies, such as fertilizer, seeds, credit, etc. may become critical, however, these industries are being expanded and such constraints are not expected to be beyond the realm of management. The expansion of food production is expected to reduce the rate of increase in food prices thereby expanding demand within the state. On a longer term it is expected that adequate food supplies of cereals will make it possible to divert land to feed grain production in support of livestock production. This diversion is not anticipated to be at a significant level within the ten years of this analysis, but should the trend in production and prices hold, some planning can be initiated in the ten years of this projection.

## Employment

The effect of farm mechanization on employment depends in large measure on government planning and participation in the mechanization process. If mechanization is carefully managed it will expand the economy and jobs will be added, but the numbers employed in rural farm jobs will be reduced while a greater number of jobs will be created in urban trade and industry. In this case study, the hired agricultural laborers must become tractor drivers rather than bullock drivers, the farmer must become a manager of a larger commercial enterprise, some laborers must move from agriculture to food marketing and input servicing, and other urban occupations will increase marginally with general economic expansion. In general, the demand for women and children in the labor force will be reduced while the productivity of permanent laborers is increased, thereby yielding counterbalancing impacts on family income and a net social gain. All members involved in these changes will require new knowledge and skills, therefore the quality of education will virtually determine the disruptive effects of this transition.

## General Development Objectives

The introduction of small tractor technology seems to be satisfactorily well balanced in that it has a favorable economic and social impact in a context of progressive governmental programs. This technology does not demand consolidation of large holdings with consequent massive dislocation of people. This technology achieves some improvement in economic structure with a modest distortion of social structure; and that distortion in the direction of "higher quality" jobs. The analysis indicates that an adequate number of jobs will be created within the immediate vicinity making the urban migration reasonable short distance travel.

## Other Considerations

The broad interactions of mechanization imply that combined with major investments of limited national resources, there is a need for careful coordination to ensure effective growth. That is, the farmers will need credit to purchase tractors and will need additional fertilizers and other inputs to achieve the additional farm production potential. A decentralized, rural, small-scale industry will need considerable assistance if it is to achieve a high capacity. And, there may be heavy demand on education to facilitate the employment shifts. The realization of much of the potential benefits will be determined by how effectively the process can be monitored and necessary developments synchronized. State and national planning agencies have machinery for this purpose, however, the introduction of small tractors will require a level of location specific and interdisciplinary attention that has not yet been developed. A major policy decision may be required to implement the precisely defined adjectives of small tractor introduction.

The concept of introduction proposed in this paper is not a simple injection of a small tractor prototype, for that has not been successful as demonstrated in several countries where Japanese power tillers have been imported and demonstrated without leading to the establishment of a local manufacturing and servicing industry. What is proposed is a coordinated, interdisciplinary program designed around the development of the 10-50 acre farm enterprise. The line of approach is suggested by farmers of these enterprises to enable them to exploit the potential productivity of that enterprise at the power availability of a 5-15 horsepower tractor rather than the power of a number of animal pairs. This is advocated as a pragmatic development program that is consistent with declared development objectives.

In summary, the attributes of small tractor mechanization are:

- it increases food production and consequently contributes to reduced food costs,
- it is an opportunity for industry, particularly rural, small-scale industry,
- it mobilizes rural savings into market transactions,
- it improves family living and working conditions,
- it is essentially domestic industry, and
- it enables further expansion of agriculture.

## APPENDIX 1. FARM PRODUCTION ADJUSTMENTS

Farming Intensity, 25 Acre Farm

| Cultivation | Consumption Percent | Consumption Acres | Marketing (acres) |
|---|---|---|---|
| 130 Percent Intensity: | | | |
| Wheat 8.75 acres | 60 | 5.25 | 3.50 |
| Rice 5.00 acres | 60 | 3.00 | 2.00 |
| Sugarcane 5.00 acres | 30 | 1.50 | 3.50 |
| Sorghum 7.50 acres | 100 | 7.50 | - |
| Pulses 3.75 acres | 100 | 3.75 | - |
| 150 Percent Intensity: | | | |
| Wheat 13.12 acres | | 5.75 | 7.37 |
| Rice 10.00 acres | | 3.30 | 6.70 |
| Sugarcane 8.75 acres | | 1.65 | 7.10 |
| Sorghum 7.50 acres | | 7.50 | - |
| Pulses 3.75 acres | | 3.75 | - |

Market Earnings

| | Price Per Acre | Acres Marketed | Income |
|---|---|---|---|
| Wheat | $120 | 3.87 | $ 464.40 |
| Rice | 90 | 4.70 | 423.00 |
| Sugarcane | 144 | 3.60 | 518.40 |
| TOTAL | | 12.17 | $1405.80 |
| Marginal Production Cost at $13.60 per acre | | | 165.50 |
| Net Income | | | $1240.29 |

Data from Problems and Prospects of Small Farms in Two Regions in Uttar Pradesh in 1969-70, Agro-economic Survey No. 2, U.P. Agricultural University, Pantnagar, U.P., Dec. 1971, Appendix B-4, B-5, B-6, B-19 and B-20.

## APPENDIX 2. LARGE-SCALE INDUSTRY DATA

Machine Tool Industry

| | |
|---|---|
| Capacity | Rs. 25.6 crores annually |
| Investment | Rs. 11.6 crores |
| Output (Value Added) | Rs. 10.24 crores |
| Employment | 8500 |
| Transport | 102,000 tons |

| | |
|---|---|
| Capacity | $34.1 million |
| Investment | $15.3 million |
| Employment | 8500 direct factory |

Using conversion ration of 19.5/34.1 = 0.57

| | |
|---|---|
| Capacity | $19.5 million |
| Investment | $ 8.7 million |
| Employment | 4850 direct factory |

Data from Techno-Economic Survey of Uttar Pradesh, National Council of Applied Economic Research, New Delhi, 1965, p. 275.

# APPENDIX 3. SMALL-SCALE INDUSTRY

Small-Scale Machine Tools and Assembly

| | |
|---|---|
| Annual Capacity | Rs. 2.0 crores annually |
| Value Added | Rs. 0.8 crores annually |
| Investment | Rs. 0.8 crores |
| Employment | 2000 |
| Transport | 4000 tons |

| | |
|---|---|
| Value Added | $1.1 million |
| Capacity | $2.7 million |
| Investment | $1.1 million |

Using conversion ration of 43.0/2.7 = 15.9

| | |
|---|---|
| Capacity | $43.0 million |
| Value Added | $17.5 million |
| Investment | $17.5 million |
| Employment | 31,800 |

Data from Techno-Economic Survey of Uttar Pradesh, National Council of Applied Economic Research, New Delhi, 1965, p. 280.

## APPENDIX 4. TRACTOR AND EQUIPMENT DISTRIBUTION AND SERVICING

Servicing and Durable Consumer Goods

| | |
|---|---|
| Capacity | Rs. 2.5 crores annually |
| Value Added | Rs. 0.6 crores annually |
| Investment | Rs. 0.3 crores |
| Employment | 6000 |
| Transport | 1000 tons |

| | |
|---|---|
| Capacity | $3.33 million annually |
| Value Added | $0.80 million annually |
| Investment | $0.40 million |

Using conversion ration of 78.8/3.3 = 24

| | |
|---|---|
| Capacity | $78.8 million |
| Value Added (x2) | $38.4 million |
| Investment (x2) | $19.2 million |
| Employment (x2) | 288,000 |
| Transport (x2) | 48,000 tons |

Note: Value added for Indian consumer goods servicing is presently only one-fourth of sales, whereas the desired level for the farm equipment industry is approximately half of sales.

Data from Techno-Economic Survey of Uttar Pradesh, National Council of Applied Economic Research, New Delhi, 1965, p. 280.

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