FARM MECHANIZATION AND AGRICULTURAL DEVELOPMENT: A CASE STUDY OF THE PAKISTAN PUNJAB

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ABSTRACT

FARM MECHANIZATION AND AGRICULTURAL DEVELOPMENT: A CASE STUDY OF THE PAKISTAN PUNJAB

By

Bashir Ahmad

This study investigated the economic and social implications of tractor mechanization in the Punjab province of Pakistan. It analyzed the influence of mechanization upon cropping intensities, yields per acre, cropping patterns, and the rate of return on investment in tractor and equipment. The social aspects include the influence of mechanization on employment of labor, tenurial relationships, and structure of farming. The method of study included (1) an analysis of the existing situation based on a field survey of a cross-section of tractor and bullock farms and (2) predictions based on a linear programming model developed for the wheat-cotton area in the Punjab. The study encompassed two systems of irrigation, canal irrigation only and canal plus tubewell irrigation. The canal plus tubewell irrigation included two cropping patterns, wheat-cotton and wheat-rice.

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The results of the field survey and the programming model indicated that, on the whole, tractor as compared to bullock cultivation led to a cropping pattern relatively dominated by high value crops but had no significant influence on the yields per acre. The lack of influence on yields was because tractor farmers lacked the necessary auxiliary equipment and had made no significant change in the use of improved inputs and practices as compared to the bullock farmers.

The most important influence of the tractor mechanization had been on cropping intensity. There were, however, important differences due to the system of irrigation and cropping patterns. Without a tubewell, irrigation water remained a constraint, and therefore, tractor cultivation had no influence on cropping intensity. As expected, the rate of return on tractor mechanization on a 50-acre farm in this area was only 3 per cent. Where tubewell water supplemented canal irrigation, tractor cultivation led to substantially higher cropping intensities as compared to bullock cultivation. The difference was greater under the wheat-cotton compared to the wheat-rice cropping system. In the wheat-cotton area the rate of return on mechanization reached 46 per cent. The rate fell to 32 per cent when major inputs and outputs were priced at the world market level. The results of the programming model indicated that the thresher with bullock in the "without" tubewell area and the t

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and the tractor with thresher in the tubewell were the most profitable forms of mechanization.

The tractor farms had relatively less family labor but used more hired labor per cultivated acre compared to the bullock farms. The structure of the hired labor on the tractor farms had changed, however, with less permanent and more casual labor being used.

Tractor mechanization led to large scale tenant ejectment. The tractor farmers resumed land for self-cultivation; they also purchased and rented land to increase the operational size of their holding. The effects of tubewell mechanization on tenants and the farm size of the owner operator were very similar to those of tractor mechanization. It is hypothesized that not only the tractor but anything that increases the productivity of land and/or increases the land handling capacity of the landlord leads to the ejectment of tenants.

Implications of this research for agricultural development policy in Pakistan are numberous. It was recommended that under the existing situation steps should be taken to encourage thresher instead of the tractor mechanization in areas without a tubewell. In the tubewell area where the adoption of the thresher instead of the tractor results in a smaller increase in productivity, the loss or gain needs to be considered against the likely benefits in the form of foreign exchange savings, improved

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off-farm linkages and, possibly, less tenant displacement. The agricultural extension service should place more emphasis on persuading the farmers to use a broader package of inputs and improved practices required to obtain optimum results from technological changes. Agricultural research can make very important contributions by shortening the growing seasons for wheat and especially for cotton, thus offsetting, at least partially, the speed advantage of the tractor in achieving higher cropping intensity. To reduce imbalanced growth between the tubewell and non-tubewell areas, diversion of some canal water from the former to the latter needs consideration.

Finally, several areas for further research have been identified. These are (1) to study ejected tenants and determine the process by which they have or have not been readjusted into the labor force; (2) to study whether there is a shortage of permanent hired labor and, if so, for what reasons; (3) to study the economic profitability of the tractor equipment and other improved inputs and practices; and (4) research towards developing short season, disease-resistant cotton varieties.

FARM MECHANIZATION AND AGRICULTURAL DEVELOPMENT: A CASE STUDY OF THE PAKISTAN PUNJAB

By

Bashir Ahmad

A THESIS

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Dedicated To

My Father

For all the sacrifices he made for my education in Pakistan that laid the groundwork for my Ph.D. study program.

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My thanks are also due to many officials of the Punjab Agriculture Department and to many of my relatives and friends in Pakistan for their generous help in the field

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survey work in the Punjab. I am grateful to the Punjab Planning and Development Department for sparing me for this study and to the Ford Foundation for financing the whole of the study program at Michigan State University and the field survey in Pakistan.

Finally, my sincerest thanks are due to my wife, Saleema, for her patience, understanding, and encouragement. Without her sacrifices this undertaking would not have been completed.

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CHAPTER I

INTRODUCTION

Technological Change, Agricultural Growth, and Development

The decade of the 1960's was marked by at least two critical developments in the theory and the practice of development economics. A concensus emerged, firstly, that agricultural growth was essential for the general economic growth and, secondly, that technological change was critical to agricultural modernization. Previously development economists associated economic growth with industrialization and were more concerned with the role of agriculture in the structural transformation than with the process of agricultural growth as such. As this issue was settled during the 1960's, the process of agricultural modernization received added attention. During the 1950's "diffusion models" based on improving the allocative efficiency of existing inputs had led to an extension bias in the choice of agricultural development strategies. The limitations of this approach became apparent as the technical assistance and the community development programs failed to generate any significant output increase in the traditional agriculture.

It was realized that it was not the allocative inefficiency but primitive technology that was the root cause of agricultural stagnation in a traditional society. T. W. Schultz in his 1964 book Transforming Traditional Agriculture (60) emphasized that peasants in a traditional agriculture are rational and efficient resource allocators but that they remain poor because in most poor countries only limited investment opportunities are available. According to him, the key to modernizing a traditional agricultural sector is to make modern "high-pay-off" inputs available to farmers and thereby change the "state of the arts." According to Ruttan and Hayami, "the significance of the (Schultzian) high-pay-off input model is that policies based on the model appear capable of generating a sufficiently high rate of agricultural growth to provide a basis for overall economic development consistent with modern population and income growth requirements" (55).

By the later sixties, some further redirections emerged in the approaches to development. It became increasingly evident that agricultural growth alone was not a sufficient condition for raising the welfare of the masses of rural inhabitants. The result was that such social objectives as employment and income distribution moved up from their peripheral position and were given equal importance with economic growth (see 12, 21, 56, and 61). Indeed, by the turn of the decade, it was being argued that growth itself in many societies was dependent upon a more equalitarian distribution of income.

In the past, however, economic growth was the overriding objective of development, and it was assumed that the growth itself would take care of the social objectives of employment and income distribution. The development policies and strategies pursued in the developing countries over the past two decades aimed at economic growth. The development programs were primarily designed to achieve a certain rate of growth in terms of real income per capita; employment was a by-product of such programs. The creation of adequate jobs was assumed to be a function of the rate of economic growth. Furthermore, in order to achieve high levels of savings and investment and, therefore, economic growth, the development strategies in the past permitted (if not encouraged) income inequality. The underlying assumption here was that as the size of the "pie" grew bigger everybody would share in the fruit of economic growth, though unequally.

Contrary to expectations, the development efforts of the past decades led to divergent trends in economic growth as compared to the social welfare consideration. Considerable evidence has accumulated that past economic growth took place without creating enough jobs (43 and 70). Furthermore, the available evidence suggests that the employment problem is likely to be even more serious during the 1970's. Millions of young people born two decades ago will be entering the labor market. According to Turnam, the labor force in the developing countries is expected to grow at 2.3 per cent per annum as compared to 1.7 per cent per annum during 1950-1965, thereby increasing the number of those requiring employment by at least 25 per cent (70, pp. 1-3). As regards the distribution of the fruits of growth, it was not only extremely skewed but also the position of certain social groups deteriorated in absolute terms. For example, the real wages of the unskilled industrial workers in Pakistan, after remaining stagnant from the early 1950's, declined by one-third during the 1960's at a time when the industrial sector was expanding at a rapid rate (see 52, pp. 12-13; 63, pp. 1-7).

Mass unemployment along with the concentration of the benefits of the economic progress in a few hands and the deprivation of the majority has already created serious social tensions, led to violent confrontation, and posed a threat to political and social stability (28, 29, 39, and 72). As might be expected, these socio-political consequences emerging from the past pattern of economic growth have proved to be more persuasive arguments for reconsidering[1] priorities than any straight forward appeal based on the welfare of the masses.

The focus on employment and income distribution has reinforced previous diagnoses concerning the crucial role

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[1]Dudley Seers, for example, proposes that employment should replace income as the target of development programs (see 62).

of the agricultural sector in development. This is due to the agricultural sector having a dominant share of the total rapidly growing population and the limited capacity of the non-farm sector to absorb more people. In most developing countries, more than 50 per cent of the total population depends on agriculture for their livelihood and jobs. With the expected rapid population growth rate of around 3 per cent per annum during the next decade or so, the available evidence suggests that the absolute number of people in agriculture will continue to grow in the near future. The manufacturing sectors in the developing countries have shown a limited employment creating capacity in the past (see 5 and 70), and the future prospects are not very encouraging. Johnston (34) has demonstrated that even a rapid growth of employment in the industrial sector in these countries in the near future can make only a minor contribution to the expansion of the total employment. Thus, given the present position and the future prospects of the agricultural sector, it is evident that agricultural development techniques and strategies and the emerging structure of agriculture will affect a large section of the society in terms of their incomes and jobs and thus will have far reaching economic and social consequences for the society as a whole.

Our previous discussion indicates that, in the context of the changed development objectives, the greatest attention is now centered on the technological change in agriculture and its economic and social implications. In order to predict its influence on agricultural output, employment, and income distribution, technology must be considered not only in relation to the nature of the resource endowment in a country but also the institutional environment and the government's policies.

A technology may be suitable to the resource endowment of a country but still have undesirable socio-economic consequences if the institutional structure and the government policies are not appropriate. For example, the technology associated with the green revolution, i.e., seed, fertilizer, and water, is considered to be appropriate to the resource endowment of most of the developing countries where capital is scarce and the land-man ratio is low. It increases output by making use of the abundant factor--labor--and augments the scarce factor--land. It is neutral as to scale and can be widely adopted, and so the gains of the technological advance are shared more equitably. Several studies (40, 45, and 57) show that the effect of the seed-fertilizer revolution on output and employment have been favorable and its adoption has been fairly dispersed. However, where there is unequal distribution of land, the large farmers with greater receptiveness to new ideas, less aversion to risk, and easy access to the input market and the technical knowledge have been the first to adopt. The small farmers have adopted after some time lag. In such a situation it is quite possible that the benefit of the new technology, in terms of the upward shift of the production function, might be squeezed out by a fall in the output prices or a rise in the input prices by the time the technology is adopted by the small farmers. The actual outcome can be determined by the government policies with regard to the output and input prices. An OECD study (77), after considering all the available survey data, concludes that the short and the long run implications of the seed-fertilizer revolution should be treated as strictly region specific. The effect may differ among regions due to the level of development, institutions, and the availability of water.

The problem of technological borrowing is most acute in cases where mechanization is involved. The introduction of machine power for farm operations is the subject of greatest controversy. The nature of the mechanical technology often is inappropriate for the resource endowment of most of the developing countries. It makes intensive use of capital and foreign exchange, the two scarcest (and, hence, expensive) resources in these countries and makes relatively less use of labor which is an abundant (and, hence, cheap) resource. It is argued that the government policies, the land tenure system, and distribution patterns, however, have led to a divergence between the private and social profitability and the widespread use of the machine power on the farms (3, 14, 15). The government policies of low interest rates, overvalued rate of foreign exchange and its preferential allocation for the import of farm machine

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machinery, rebates on fuel, subsidized training for drivers and mechanics, and subsidized repair facilities reduce the capital and the variable cost of the farm equipment and machinery considerably below their social opportunity cost. Moreover, where land distribution is skewed, the labor costs to the large farmers who pay the market wage rate are greater than the social opportunity costs. Given these factor prices, it becomes profitable for large farmers, with greater access to land and capital, to use capital intensive technology.[1]

In the controversy over the farm mechanization, many take extreme positions. In the scheme of agricultural modernization suggested by some there is no place for the tractor (46). There are others who think that increasing the use of tractors (and only big tractors) is the only way to increase agricultural production (23). A range of intermediate steps are, however, available. Emphasis on stationery threshers and tractors used for seed-bed preparation only has been suggested to break the seasonal peak labor and bullock power bottlenecks (32). The problem with tractors, however, is that once the machine power is

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[1]Keith Griffin (22) provides a very good theoretical basis of how a distortion of the input prices leads to a non-optimum technology from the social point of view. It becomes clear from his analysis that the actual technological path may diverge from the socially optimum path of Ruttan and Hayami's (55) "Induced Development Model" when their assumptions about the institutional structures do not hold.

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It is mechanization in the form of large tractors and combine harvestors that is the subject of much of the controversy. The most serious concern about the mechanical technology arises from its predicted social consequences. Tractors, it is said, pose a conflict between growth and social justice. Alternative technologies are available which can increase output and employment and spread the benefits more evenly. Often cited as examples are Japan and Taiwan, where technological change has been of the land-augmenting and labor-absorbing type, increasing agricultural employment and more equitably shared output. It is argued that tractor power, by speeding up the farm operations, would lead to displacement of labor and accentuate the already serious unemployment problem. Moreover, the tractor, being a "lumpy" input, has economies of scale and gives a cost advantage to the large farmers. In order to realize the economies of scale and reduce their average costs, the large farmers would expand the size of their farm through displacement of tenants and the purchase of new land (provided there are no legal limits on the farm size). If higher production on the larger farms leads to excess supply and a fall in the output prices, this will be disastrous for the small farmer who does not share in the benefits of the technology but loses due to a fall in his output prices. This process, it is argued, would lead to a "bi-modal" distribution of the farm size and polarization of society with serious consequences for the social and political stability (see 77, 22, 37, and 35).

In favor of tractor mechanization, it is argued that custom services can deal with the scale factor and small farmers can also benefit. The tractor power allows timely and effective farm operations (deep tillage that would activate the soil fertility) that increases per acre yields. Speeding harvesting and land preparation allows multiple cropping, which increases labor productivity and employment. Labor may be displaced on particular operations, but the overall employment increases due to the increase in the cropping intensities, higher yield, change in cropping patterns, etc. Tractors replace bullocks and so release the fodder land for food crops (see 64, 58, 36, and 41).

It is generally agreed that mechanization will have very far-reaching consequences for the socioeconomic structure of the societies where it is being introduced. According to Shaw (64), "So important is mechanization in defining the future of the agricultural sectors in the developing countries that their governments should give the highest priority to conceiving coherent national strategies to deal with the whole set of issues raised." There is not, however, enough information on the economic and social consequences of the mechanical technology to serve as a basis for a general policy for or against mechanization. According to Ridker,

> There is so little information and the little that exists is of such poor quality that we just can not say with confidence much about the nature of the problem, let alone what, if anything, should be done about it. . . . Any general recommendation on mechanization appears to be out of the question at this juncture. The effects appear to be highly specific to the form of mechanization applied, to cropping patterns, and to geographic regions. (58)

Overview of Several Major Studies on Farm Mechanization in Asia

A Review of several major studies (along with the theoretical arguments for and against mechanization discussed in the previous section) will be useful in a number of ways. It will help to delineate the objectives of the study, to formulate the hypotheses to be investigated, and to suggest how to design this study.

In recent years, a number of relevant studies have been conducted in India. Baghat Singh (65) studied twenty-eight wheat farms in four districts of the Indian Punjab to assess the benfits of the use of tractors. He concluded that:

1. The cropping pattern on the tractor farms shifted from low to high value crops.

2. The use of tractors did not affect the cost of cultivation of wheat per maund.

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> labor. As a result, the tractor farms used less labor per acre as compared to the bullock farms.

Singh concentrated on one crop (wheat) only and did not examine the employment pattern of the tractor farms for all crops and all agricultural operations on an average annual basis. The average size of the holding for tractor owners was more than twice that of the non-owners. Such a big difference in the farm size weakens the comparability of the two types of farms. The shift in the cropping pattern from low to high value crops on the tractor farms identifies an aspect that could contribute to the profitability of a tractor.

Another study, also in the Indian Punjab, was made by S. S. Johl in 1971 (36). Using secondary farm management data for a sample of progressive farmers for the period 1966-67 to 1969-70, he concluded:

> Over a period of four years average cultivated area increased by about 11 per cent. Cropped area increased by over 26 per cent with an overall intensity of cropping increasing from 126.69 per cent in 1966-67 to 144.26 per cent in 1969-70. As a result of this expansion in crop acreage horizontally as well as vertically labor-use on the farms increased by over 58 per cent during this period. This increase in intensity was made possible through the use of tractor power and water pumping machines. Tractor power use increased by over 44 per cent. Tractors and pumping sets coupled with wheat thrashing machines replaced bullock power, reducing its use to less than 28 per cent of what it was in 1966-67. These data show a high degree of complementarity in mechanical power use and labor employment on farms. Substitution took place only for bullocks (animal draft power).

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Singh highlighted the important mechanisms by which use of the machine power may lead to higher output and employment at the same time. His mechanization package, however, consisted of threshing machines, water pumping machines, and tractors. It is generally agreed that water pumping machines and threshing machines will have positive output and employment effects; it is the tractor that is the subject of controversy. There is no way to separate the effect of the tractor from the other two types of machinery in this study.

A study in the Pakistan Punjab (24) on the output effects of tubewell alone showed that cropping intensities increased from an average of 90 to 135 per cent and labor input increased by 57 per cent after the installation of the tubewells. (The study was undertaken before the intro-cution of high yielding varieties of foodgrains.) The two figures are very comparable to the output and employment effects given by Singh. However, Singh's study covered a period during which the high yielding seed varieties were spreading rapidly. When agriculture is undergoing such a rapid all-around technological transformation, a cross-sectional study would be more relevant than a time series analysis.

Johl quoted another study (53) to show that yields per acre were higher for all crops on the tractor farms. In the absence of information on the use of the accompanying inputs, the farm size, etc., it is hardly appropriate to attribute the higher yeilds to tractors. Cline (8) attempted to separate the effects of mechanization on yeilds from the influence of other inputs using data for 117 rice farms in the south of Brazil. His results showed a statistically significant positive effect of mechnaization on yields, but the magnitude of the influence was small. Singh also showed a substantial increase in the non-farm employment for the manufacture, repair, and sale of agricultural machinery.

Two other studies in different parts of India focused on employment effects of tractor mechanization. While the study in Mysore State (66) concluded that mechanization leads to some displacement of labor, the study in the state of Uttar Pardesh (73) indicated positive employment effects.

Inukai (32) studied the effect of tractor mechanization on the labor input and output of rice in Thailand. He showed that although the use of the tractor for land preparation reduced the demand for labor for this particular operation, it led to an increase in the total labor input per unit of land. Deep and timely plowing by the tractor increased the yield per acre, which also increased the demand for labor. The rapidity of land preparation enabled the farmers to change the method of rice sowing from broadcasting to transplanting. The transplanted rice increased both the yield per acre and the labor requirements for sowing and harvesting. He concluded, "In a dynamic setting, selective mechanization may create more jobs than it elimi

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eliminates." In fact, "these labor-saving devices [such as tractors, diesel pumps, and medium-sized tubewells] have provided farmers with an opportunity to spread work over several seasons. As such, they have on balance enabled farmers to increase the labor input to their agriculture."

Using macro level secondary data, this study attempted to establish likely linkage between tractor mechanization and higher farm output and employment. Examination of such a relationship would be helpful in organizing future research on mechanization. The study, however, provided no guidance for the policy makers.

A number of studies have been undertaken in Pakistan on various aspects of mechanization. Bashir Ahmad (2) of the Agricultural University, Lyallpur, studied the economics of bullock farming versus tractor farming in the Lyallpur district of the Punjab. He concluded that the tractor farms grow more cotton and fruits (the relatively high value crops) as compared to the bullock farms which had relatively higher acreage under cereals, fodder, and sugarcane. The cropping intensity was almost the same on both types of farms. The yield per acre of wheat, cotton, and maize was higher on the tractor farms, but the difference was not significant statistically. The labor input per acre was significantly lower and capital input higher on the tractor farms as compared to the bullock farms.

In this study the average size of the tractor farm was more than five times the size of the bullock farm. Such a big difference in size seriously affects their comparability. Different studies (24, 32) show that both intensity and yield per acre tend to decline with increase in the size of the farm.

Bose and Clark (6) looked into the profitability of tractor mechanization in West Pakistan. Their analysis concluded that at full tractor mechanization,[1] the direct costs to society would be about 300 million rupees, and the direct benefits would be around 200 million rupees. The indirect costs, including unemployment of farm labor, would be much greater than the possible indirect benefits. The mechanization is, therefore, not socially profitable. But it is profitable to the farmer because of divergence between both social and private costs as well as benefits. In their analysis, Bose and Clark assumed that an alternative technique in the form of improved bullock implements and threshers (selective mechanization) is available which will enable the farmers to handle the seasonal power bottlenecks and prepare the land effectively. They argued that from a social point of view it is not the power but water which is a constraint to the higher cropping intensities. With these assumptions, the findings of their analysis do not include any yield and cropping intensity effect of mechanization. They also made no allowance for a shift in

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the cropping pattern. According to their analysis, the only direct social benefit of mechanization would be the value of the alternative crops that can be raised on the fodder area released as a result of elimination of bullocks.

This study suggests a useful framework for analyzing the private and social costs and benefits of tractor mechanization. However, it is not helpful for policy formulation because of its hypothetical data and assumptions, which have not been tested against empirical evidence.

Lawrence (41) made a more recent study in Pakistan. He considered a situation where water is no constraint and a farmer is cultivating a wheat-cotton crop sequence using traditional techniques. By using farm budgeting techniques, he showed that the introduction of mechanical power in the form of the thresher, tractor, and a pull combine will reduce the time required for wheat harvest-cotton sowing and shift the cropping intensities from wheat-cotton-cotton over a two year period to wheat-cotton-wheat-cotton. Moreover, the per acre yields will increase due to deeper tillage and timely sowing and row cropping. He concluded,

> There is a consistent downward trend both in the market and opportunity costs of a unit of production as one moves from techniques involving less mechanization to techniques involving more mechanization. The persistent downward trend also indicates that emphasis on so-called intermediate technologies involving improved bullock implements and stationary threshers is misplaced . . . There appears to be a clear-cut case for mechanization up to and including use of tractors and pull combines when a wheat-cotton sequence is being farmed.

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> The labor demand for field operations fell only slightly when tractors were introduced, and lower levels of mechanization actually increased labor demand. Combining, on the other hand, does reduce the demand for field labor considerably. . . .

The study by Lawrence revealed that mechanization might open up new possibilities in a given situation, but his conclusions are not applicable in other situations where tubewell water is not available, where water becomes a constraint, and also where soil and climate conditions permit only wheat-rice crop rotations. There are large areas of the latter two types in Pakistan. Also, he purports to use "social prices," but if there is not enough water to go beyond 150 intensity, we must introduce water as a "scarce" resource to the economy.

This review of mechanization indicates that the different studies bring out conflicting conclusions with regard to the influence of mechanization on output, employment, and profitability. The conflicting conclusions are largely due to differences (1) in the form of mechanization considered; (2) in the coverage of the study, i.e., the number of crops and crop operations covered to assess the influence of mechanization; (3) in the situational characteristics in terms of sources of water supply, availability of technically feasible crop sequences, size of the farm, quality of the soil, etc.

The mechanization considered by some of the studies included tubewells, threshers, tractors, and even combines.

However, most of the studies were confined to tractor mechanization. It should be realized that the influence of the tractor on output and employment will depend on the accompanying implements and equipment and the use of the tractor. A tractor using a mouldboard plow, row crop planter, and cultivator will have different effects on yields as compared to a tractor using only a cultivator. Similarly, the employment and output effects of a tractor will be different if used only for land preparation than when its use is extended to post-sowing operations like hoeing and post-harvest operations like threshing. None of the studies took into consideration the tractor implements and equipment and the uses of the tractors.

Some studies, assuming a static setting for the farm firm, considered only one crop and one or few operations to assess the benefits of mechanization. The review as a whole, however, indicates that the introduction of a tractor will infuse a dynamism into the structure of the farm firm leading to a change in the cropping patterns, cropping intensities, number of operations performed per crop, intensity of such operations, yields, etc. To determine the influence of mechanization on employment, output, and profitability, therefore, we should take into consideration all crops and all operations and the total effect on the average annual basis.

As characteristics may differ among regions in the same country, the conclusions emerging under one situation may not be relevant for another. This necessitates separate studies for different situations or a sufficiently comprehensive study to accommodate a sample of regional variations.

The Objectives of the Study

The first major breakthrough in the introduction of machine power in Pakistan's agriculture took place during the 1960's with the use of diesel engines and electric motors for pumping the underground sweet water. This led to a rapid tubewell development during the 1960's which continues up-to-date. The socio-economic impact of the private tubewell development has been intensively explored (9, 10, 24, 25, and 44). These studies concluded that the availability of additional and flexible water supply on the tubewell farms resulted in substantial increases in output and employment. Besides direct increases in on-farm employment, tubewells also created substantial employment opportunities through backward linkages in the non-farm sector (19, 67).

The next major thrust in farm mechanization appeared in the form of tractors, whose number in West Pakistan increased from 1000 in 1959 to 19,000 in 1968-69, with 73 per cent of the total number coming in the three-year period from 1965-66 to 1968-69. More recently, thre

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threshers and combine/harvesters have been added to the list of mechanical farm technology. Some studies (41, 74) have recently been made on threshers and combine harvesters. Their general consensus was that the overall socio-economic impact of the use of threshers will be favorable and those of combine harvesters unfavorable.

As revealed from the review of the previous studies on mechanization, tractor mechanization has not been adequately explored, and its socio-economic implications still remain a subject of controversy. To decide the future policy on mechanization, the government of Pakistan in 1968 set up a Farm Mechanization Committee for West Pakistan. This Committee has emphasized the need for research. To quote, "The Committee can't escape the conclusion that research and development has been the weakest link in the progress of Farm Mechanization. . . . Research on socio-economic aspects must receive the highest priority to provide necessary guidance" (48).

The overall objective of the present study on the tractor mechanization in the Punjab Province of Pakistan is to attempt to find answers to some of the questions raised by the policy makers. Specifically, the study's major objectives are the following:

1. To identify and measure the effect of farm mechanization on agricultural output.
2. To identify and measure the effect on farm employment.

3. To investigate the tenant-landlord relationships and the effect of mechanization on the structure of the farms operated by landlords and tenants.

4. To study and estimate the private and social profitability of the mechanization.

The Conceptual Framework

The following conceptual framework will serve as a guide for the study.

1. Mechanization can affect output through the following variables.

   a. The yield effect: change in the yield per acre per crop.

   b. The cropping intensity effect: change in average number of crop acres raised per cultivated acre per period.

   c. The cropping pattern effect: change in the cropping pattern between high value and low value crops.

   d. The acreage effect: change in the total area under cultivation per farm.[1]

2. Similarly, the change in the labor input on a mechanized farm could be studied through the following framework.

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[1]This variable will not be taken into consideration because of the likely divergence between the micro and the macro acreage effect.

a. The operations effect: change in the labor intensification of the already existing farm operations, i.e., higher labor use for harvesting when crop yields increase and lower labor use for land preparation when the tractor replaces the bullocks. Moreover, the number of farm operations may change: some new operations may be added or some old ones eliminated.

b. The cropping pattern effect: crops with higher intensity per acre may be substituted for those with lower labor input requirements per acre, i.e., fruits or vegetables may replace part of the grain area.

c. The cropping intensity effect: multiple cropping would increase the labor use per cultivated acre per period.

d. The acreage effect: increase in the total area under cultivation could lead to greater demand for labor. Again, this variable will not be considered in our study for the reasons given in the previous section.

3. The effect of mechanization on the tenant-landlord relationships and the farm size could be examined through the following.

a. The share effect: the ratio of the cost of inputs and output for the tenant to those for the landlord might change after the landlord buys a tractor. The mechanized landlord might now insist on changing the share ratios in his favor because of his increased capability to handle larger areas himself.

b. The terms effect: for the reasons given above, mechanization might change the cash tenancy into share cropping, thus transferring the managerial functions from the tentant to the landlord.

c. The farm size effect: the mechanized landlord might increase the size of his operational holding through:

   (1) partial tenant displacement whereby tenant is allowed to retain a reduced holding;

   (2) complete tenant displacement whereby the tenant is altogether evicted, reducing his holding to zero;

   (3) indirect tenant displacement whereby the mechanized landlord increases his operational holding through renting in land.

4. Profitability of farm mechanization can be investigated according to one of two approaches:

   a. Mechanization as an alternative source of power in a static farming system: This approach assumes that the replacement of bullock with tractors induces no other change in the combination of products and inputs. The investigation of profitability of mechanization involves comparison of the cost of machine power with that of bullock power per cropped acre (see 30).

b. Mechanical power as an initiator of dynamism in the farming system: This approach assumes that the introduction of the tractor changes the resource availability along with some of the input-output coefficients to which the profit-maximizing farm firm will respond by changing the level and combination of his inputs and outputs. Following this approach, Lawrence used the farm budgeting technique in his study in Pakistan (41). In the present study we shall also follow this approach but develop a programming model for a fifty-acre mechanized farm in the Punjab Province of Pakistan.

Organization of the Study

The present chapter has been a description of the basic framework for the study of tractor mechanization in the Punjab. The following chapter will provide background information, including a discussion of the general features of agriculture, government policies regarding mechanization, and the pattern of mechanization that has emerged.

Chapter III will present a description of the design and procedure of the farm level field survey undertaken in the Pakistan Punjab in winter, 1972. In Chapter IV the survey data will be analyzed and the resulting conclusions will be presented. Chapters V and VI will be devoted to a normative study of farm mechanization. In Chapter V discussion will be made of (1) the development of the linear programming model for a representative farm firm in the Pakistan Punjab and (2) the results of the basic solution of the model. Chapter VI will involve an analysis of the sensitivity of the programming model results to changes in (1) the farm size, (2) the tubewell water, and (3) the prices of agricultural machinery and commodities.

In Chapter VII, the study and its conclusions will be summarized, the policy implications of these conclusions will be discussed, and areas for further research will be indicated.

CHAPTER II

CHARACTERISTICS OF AGRICULTURE, GOVERNMENT POLICIES, AND DIFFUSION PATTERN OF FARM MECHANIZATION IN WEST PAKISTAN

Characteristic Features of Agriculture in West Pakistan

West Pakistan consists of four provinces: the Northwestern Frontier Province, the Punjab, the Sind, and Baluchistan. Although the present study relates to the Punjab alone, this section highlights some of the major structural elements of agriculture in Pakistan in order to serve as a context for the study.

Natural Endowments--The Land and the Water

The geographical area of West Pakistan is 199 million acres. However, as an index of productive resource to provide a base for agricultural production, this figure is very deceptive. As shown in Table 2.1, of 199 million acres only 79 million acres, i.e., 39.7 per cent of the total area, was available for cultivation in 1967-68. Further, out of the 79 million acres available for cultivation, 31 million, i.e., about 40 per cent, remained out of cultivation because of the lack of water. The area

TABLE 2.1.--Land Utilization in West Pakistan and the Punjab 1967-68.

	Area in Million Acres		Punjab as % of Pakistan
	Pakistan	Punjab	
1. Total geographical area	198.6	51.0	25.7
2. Area not reported	67.2	9.2	13.7
3. Total reported area (1-2)	131.4	41.8	31.8
4. Area not available for cultivation			
a. Forest area	5.6	1.0	
b. Other area	46.8	7.4	
Total	52.4	8.4	16.0
5. Total area available for cultivation (3-4)	79.0	33.4	42.3
6. Culturable waste area	31.4	6.9	22.0
7. Total area cultivated (5-6)	47.6	26.5	55.7
8. Total cropped acreage	38.8	24.7	63.6
9. Average cropping intensity	81.5%	93.2%	

Source: West Pakistan, Department of Agriculture, Season and Crop Report of West Pakistan for the year 1967-68. (Lahore, 1968) under cultivation in 1968 was only 48 million acres on which 39 million acres of crops were raised, giving an overall cropping intensity of 82 per cent. The Province of the Punjab with 26 per cent of the total geographical area has 56 per cent of the total cultivated area of West Pakistan. This indicates the importance of the Punjab in the agriculture of West Pakistan.

The cultivated land area alone, however, is not a good indicator of the productive capacity. It is the water along with the land which determines the production base available. In general, the country has an arid and semi-arid climate with hot summers and cold winters. The rainfall is low and variable over space and time. In the Northern areas precipitation is above 25 inches per annum. But in the upper Indus Plain, which consists largely of the Punjab, the rainfall varies from 25 to 10 inches. In the Sind and Baluchistan Provinces, it is less than 10 inches per annum.

Moreover, rainfall is concentrated in a few months of the summer and the winter. The low and variable rainfall is the main reason why large segments of the land area available for cultivation could not be brought under the plow.

As shown in Table 2.2, out of 48 million acres under cultivation in 1968, 17 million acres had no other source of water except rain. In general, the rainfed areas are

TABLE 2.2.--The Cultivated Area (in Million Acres) and the System of Water Supply in West Pakistan in 1967-1968.

	Total Cultivated Area	Un-Irrigated (Rainfed) Cultivated Area	Irrigated Cultivated Area					
			Total	Canal Irrigated	Tubewell Irrigated	Well Irrigated	Tank Irrigated	Others
West Pakistan	47.6	16.7	30.9	22.1	2.9*	2.1	0.03	3.8
Punjab	26.5	5.8	20.7	14.4	2.8*	1.9	0.03	1.6
Punjab as % of West Pakistan	55.7	34.7	67.0	65.4	96.5	90.5	100.00	42.0

Source: As for Table 2.1.

*Area irrigated by tubewells only. Tubewells are much more important as a source of supplementary water on the canal irrigated area. Sixty-six per cent of the total tubewells in 1969 were on the canal irrigated farms (48).

characterized by low level of cropping intensity and low yields. Under the climatic conditions of West Pakistan, irrigation is essential for intensive cultivation. Historically, land has been irrigated mainly with the surface water. As indicated in Table 2.2, 22 million acres, i.e., 71 per cent of the total irrigated area of 31 million acres, received canal water in 1968.

The development of tubewells during the last decade and a half has added another important source of water. In 1968, about 3 million acres were dependent on tubewell water alone. But the major contribution of the tubewells has been in providing supplementary water to the areas already irrigated by canals. Sixty-six per cent of the total tubewells have been installed in the canal irrigated areas (48, p. 61). The canals supplied only a limited amount of water permitting a cropping intensity varying from 80 to 100 per cent.[1] The tubewells have provided a dependable and a flexible source of water, removing the historical water constraint and uncertainty and thereby raising intensities and yields.[2]

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[1]As mentioned in (76) the quantity of the canal water to be supplied was determined by the canal authorities with a view to permitting 80 per cent intensity. The farmers in the canal irrigated areas, however, reach a 100 per cent intensity partly due to the estimate generosity of the canal authorities and partly due to their thin spreading of the water.

[2]By the end of 1967-68 about 76,000 private tubewells had been installed with an average capacity of 1.4 cusecs which provided about 20 million acre feet of

As the empirical data will indicate, the major thrust of the tractor mechanization has been on these canals and on tubewell water farms. Tubewells, by removing the water constraints, appear to have created a power constraint, especially on the large farms.

The Punjab with 56 per cent of the total cultivated area of West Pakistan (Table 2.1) has 67 per cent of the irrigated cultivated area (Table 2.2). Sixty-five per cent of the canal irrigated area and 96 per cent of the area irrigated by tubewells alone are in the Punjab. About 91 per cent of the total private tubewells have been installed in the Punjab (see 48, Table 33). The relative amount of water along with the cultivated land area in the Punjab clearly identify the pivotal position of the area in the agricultural economy of West Pakistan. This is reflected in its share of the major crops area as shown in Table 2.3.

The crop list in Table 2.3 indicates a considerable diversification in crop production. The aggregate value, however, is dominated by a small number of crops. Wheat alone accounts for 39 per cent; combined with rice and cotton, the three crops comprise 60 per cent of the total cropped area.

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additional water (48) annually to supplement the 60 million available from the canals (31). The success story of the rapid agricultural development in West Pakistan during the 1960's has been described largely in terms of the addition of tubewell water (see 20).

TABLE 2.3.--The Cropping Pattern in West Pakistan and the Punjab in 1967-68.

Crops	West Pakistan		Punjab		Punjab as Per Cent of West Pakistan
	Area in Thousand Acres	Per Cent of West Pakistan Area	Area in Thousand Acres	Per Cent of Punjab Area	
Wheat	14,657	39.0	10,559	43.2	72.0
Rice	3,510	9.4	1,650	6.7	47.0
Barley	434	1.2	248	1.0	57.0
Maize	1,501	4.0	728	3.0	48.5
Jowar	1,666	4.4	789	3.2	47.4
Bajra	2,235	6.0	1,204	4.9	53.8
Gram	2,697	7.2	1,882	7.7	69.8
Tobacco	173	0.5	82	0.3	47.4
Sugar cane	1,245	3.4	935	3.8	75.1
Cotton	4,413	11.8	3,290	13.5	74.5
Fodder	1,224	3.3	1,142	4.8	93.3
Oilseeds	1,708	4.6	851	3.5	49.8
Pulses	1,188	3.2	632	2.6	53.2
Fruits	418	1.1	202	0.8	48.3
Vegetables	340	0.9	246	1.0	72.3
Total	37,409	100.0	24,440	100.0	65.3

Source: As in Table 2.1.

Land and People

The total population of West Pakistan in 1968 was estimated to be 58.3 million, of which 34.8 million or 59.3 per cent lived in the Punjab (52, p. 547). According to the Population Census 1961 (51) 77 per cent of the total population of West Pakistan lived in the rural areas and 75 per cent were directly dependent on agriculture for their livelihood.

As shown in Table 2.4 the total labor force in West Pakistan in 1961 was 12.8 million, agriculture's share of

TABLE 2.4.--The Share of Agriculture in the Total Labor Force in West Pakistan. (Numbers in Thousands)

Years	Labor Force			Percentage Share of Agricultural Sector
	Total	Non-Agricultural	Agricultural	
1951[a]	9,507	3,319	6,188	65.1
1961[a]	12,763	5,193	7,570	59.3
1965[b]	14,359	6,211	8,148	56.7
1970[b]	16,637	7,769	8,868	53.3
1975[b]	19,276	9,718	9,558	49.6
1980[b]	22,334	12,156	10,179	45.6

[a]Census

[b]Projections

Source: Hiromitsu Kaneda, "Economic Implication of the 'Green Revolution' and the Strategy of Agricultural Development in West Pakistan," Pakistan Development Review, IX (Summer, 1969), 111-143.

which was about 59 per cent. According to the projections given in the table, the agriculture labor force will continue to grow in absolute numbers at least to 1980.

Table 2.5 reports the distribution of the total agriculture labor force in 1961 among the cultivators, the

TABLE 2.5.--The Percentage Distribution of the Agricultural Labor Force in West Pakistan by Tenure in 1961.

Category of Tenure	Percentage of the Agricultural Labor Force
Farm Operators	64
Owner-operators	(26)
Owner-cum-tenant	(9)
Tenants	(29)
Unpaid family labor	28
Landless agriculture laborers	8
Total	100

Source: Pakistan Ministry of Home and Kashmir Affairs, Census of Pakistan Population 1961, Vol. 3, Karachi, 1963.

landless laborers, and others. The cultivators, in the form of owner operators and tenants, provided 64 per cent, and another 28 per cent of the labor was provided by their family members. The landless agricultural laborers provided only 8 per cent of the total labor force.

Farm Size and Distribution of Landholdings

According to the Pakistan Census of Agriculture 1960 (47), the average size of the farm in West Pakistan in that year was 10 acres, of which 7.7 acres were under cultivation. The distribution of the landholdings, however, is very skewed. As shown in Table 2.6, 49 per cent of the farms

TABLE 2.6.--The Percentage Size Distribution of the Farms and the Farm Area in West Pakistan 1960.

Size of the Farm (Acres)	Percentage of the Farms	Percentage of the Farm Area
less than 5	49	11
5 to under 12.5	28	25
12.5 to under 25	15	29
25 to under 50	6	20
50 to under 150	2	10
150 and above	*	5
All sizes	100	100

*Less than 0.5.

Source: Pakistan Ministry of Agriculture and Works, Pakistan Census of Agriculture 1960, Vol. II, (West Pakistan, October, 1963).

have holdings below 5 acres and comprise only 11 per cent of the total farm area. On the other hand, only 8 per cent of the farms have holdings of 25 acreas and above and constitute 35 per cent of the total farm area. According to the various indications (see 6, 37, and 35), it is these 8 per cent of the farms which are mainly susceptible to the tractor mechanization.

The data also show (see Table 2.7) that in terms of numbers the tenant farms were slightly more common than

TABLE 2.7.--The Percentage Distribution of the Farm Operators and the Farm Area by Tenure in West Pakistan in 1960.

Type of Tenure	Percentage of the Farms	Percentage of the Area
Owner operated	41	38
Owner-cum-tenant	17	23
Tenant operated	42	39
All types	100	100

Source: Same as for Table 2.6.

those operated by owners. The tenants operated 42 per cent of the farms with 39 per cent of the total farm area as against 41 per cent of the owner operated farms with 38 per cent of the total farm area. These figures emphasize the weight of the tenants in West Pakistan's rural economy.

Government Policies with Respect to Mechanization[1]

The government's policy with respect to technological change could be either "passive" or "active." When

[1]This section draws heavily on the report of the Farm Mechanization Committee (48). Unless otherwise indicated the Committee Report will be the source of information.

passive, it provides no signals through its incentive and disincentive mechanisms. An active government policy, on the other hand, uses the various policy instruments at its disposal either to encourage or to discourage a technological innovation. This section will review the government's policies in the various spheres that have a bearing on mechanization.

Import Policy

Pakistan meets its tractor and agricultural machinery requirements almost entirely from imports. With scarce foreign exchange resources, its allocation and rate have a considerable influence on the availability, prices, and, hence, the demand for tractors and other machinery. Unrestricted foreign exchange allocation at the official exchange rate[1] was available for the import of tractors to the commercial importers until 1952 and to the individual farmers until the end of 1966. The allocation was severely restricted after 1966 and completely stopped in 1969.

The foreign exchange allocations at the overvalued official rate provided an important incentive for the import of the tractors. According to the Farm Mechanization Committee Report, "The present (1968-69) annual import of around 35 hundred tractors leaves an unsatisfied demand for

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[1]The official exchange rate during the past few years has been Rs.4.70=$1 which has been now revised to Rs11=$1. This indicates the extent of overvaluation in the rate of foreign exchange.

at least an equal number of tractors." However, when foreign exchange allocation at the official rate was stopped in 1968 and the tractor importers were required to buy foreign exchange in the open market at rates varying between Rs.8-9 to a dollar, no import took place. Many argue (see 6 and 37) that tractor use in West Pakistan would not have been profitable to the farmers without the preferential allocation of foreign exchange at the overvalued official rate. Lawrence (41), on the other hand, presents this view:

> What is frequently overlooked is that agricultural output is also underpriced by the present exchange regime. In the cropping sequence considered here [in his study], it is clear that the underpricing of mechanical equipment has been almost exactly offset by the underpricing of output.

The import of diesel oil is subjected to heavy import duty and other taxes. The market price of diesel oil in West Pakistan is more than double its social cost. The author's discussion with the Ministry of Agriculture and Works and the Planning Commission indicated that they believe the lower social cost of diesel at least compensates for the higher social cost of tractors. So, on the whole, the cost to the farmer of the machinery in operation is the same as to society, but he pays too little for the capital equipment and too much for the variable costs to operate it.

Taxation Policy

Agricultural machinery was given a preferential treatment and no taxes were levied up to July, 1969, at a time when the industrial machinery was subjected to a custom duty and a sales tax of 35 per cent (1). From 1969 onward, custom duty, sales tax, defense surcharge, and a rehabilitation tax amounting to about 25 per cent of the import value of agricultural machinery have been levied. No registration fee is charged, and the tractors do not have to pay the road tax if not used for non-agricultural commercial purposes. Thus, the preferential treatment continues but at a much lower rate, as compared with industrial machinery.

Credit Policy

The institutional sources in Pakistan provide only 15 per cent of the agricultural credit (see 1), and the remaining 85 per cent comes from private sources, namely friends, relatives, landlords, village shopkeepers, rural money lenders, and commission agents. The private sources, though important for short-term credit, cannot provide the large amounts needed for the purchase of agricultural machinery. So far as institutional credit is concerned, cooperatives and government Taccani loans are mainly for short and medium term lending, and the Agricultural Development Bank is the only major source of loans for the purchase of the agricultural machinery. In the four-year period from 1965-66 to 1968-69 the Bank sanctioned loans worth Rs.462 million in West Pakistan, of which 51 per cent was for tractors, 27 per cent for tubewells, and 22 per cent for all other requirements. The major sources of financing the purchase of the tractor, however, have been the farmers' own resources, accounting for 62 per cent of the total amount while loans provided 38 per cent (see 50, Table 25).

The Bank provides loans at a subsidized interest of 9 per cent per annum.[1] For tractor loans, farmers holding less than 75 acres of land are not eligible for the loan purchase of the tractors received under International Development Association credit.[2]

Other Policies

Government provides free training for drivers. In the past, besides free training, each trainee was provided a stipend. Repair workshops have been established in important agricultural districts. A subsidy of about 35 per cent is provided by the government on its tractor custom work, but their main use is for land development.

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[1]Lawrence (41) used 15 per cent per annum rate of interest as an opportunity cost of lending in Pakistan.

[2]"In recent years the dollar credits received from IDA by the Bank have constituted the major source of funds for loaning purposes. IDA has put some restrictions on the use of their funds under which the Bank is required to provide the machinery on loan to the farmers and it cannot be sold against cash. Another condition is that farmers with less than 75 acres of land are not eligible for the purchase of tractors received under IDA credit." (48, p. 125)

Diffusion Pattern of Farm Mechanization in West Pakistan

This section will discuss farm mechanization patterns as they emerge from the results of the survey "Farm Mechanization in West Pakistan" (60) conducted by the Pakistan Agriculture Census organization in 1969. This discussion will be helpful in determining where and what to look for in the present study of socioeconomic implications of mechanization in West Pakistan.

Ownership Pattern

The implications of the tractor mechanization will differ depending on who owns the tractor--the government, the cooperatives, or individual joint owners. In 1969, there were about 19,000 tractors in West Pakistan. Their ownership pattern is shown in Table 2.8. It is clear from the table that the tractor ownership is heavily concentrated in private hands and ownership by the government and the cooperatives is insignificant. The government's share consists mostly of crawler tractors for land development purposes. Among the private owners, joint ownership is very low, while individual owners, with 74 per cent of the total tractors, hold the major share. Thus the mechanization pattern has placed tractor power mainly in the hands of

TABLE 2.8.--Ownership Pattern of Tractors in West Pakistan, 1969.

Owners	Percentage of the Total Tractors Owned
Private owners	86
Individual ownership	(74)
Joint ownership	(12)
Government and semi-government agencies	12
Cooperatives	2
All owners	100

private individual owners, thereby limiting its common sharing except through the custom services.

Mechanization Pattern and the Holding Size

It is the perceived economies of scale which determine for which size farm the purchase of a tractor is likely and, hence, which farms hold a central or peripheral position in the mechanization process. Furthermore, given the horsepower of the tractor, its holding size distribution pattern determines the extent of the excess power available. The potential excess capacity could be utilized, excluding the non-farm uses, either for hiring out tractor services or increasing the ownership and/or operational size of the holding. These two adjustment possibilities, the first where the tractor power is adjusted to the existing size of the farm through custom operations and the other where size of the farm is adjusted to the tractor power through purchasing and/or renting in more land, will, evidently, produce quite opposite farm structures and social consequences. In West Pakistan, the most common size of the tractors in 1969 was 36 to 55 H.P. with 75 per cent of the total wheel type tractors falling in this category (Table 2.9). Only 1 per cent of the tractors were 25 H.P. and

TABLE 2.9.--Percentage Distribution of Tractors by Horsepower in West Pakistan, 1969.

Horsepower	Percentage of the Total Wheel Type Tractors
Less than 25	1
26-35	15
36-55	75
56-66	8
67 and above	1

below and 16 per cent 35 H.P. and below. Thus, West Pakistan (following the advice of international institutions and experts)[1] has concentrated on relatively larger tractors.

[1]The World Bank in their study in 1966 (see 30, Chapter 11, Mechanization) recommended that ". . . in order to catch up in mechanization standards farmers in underdeveloped areas should jump some of the stages of development that the pioneers have of necessity to undergo. If they are led upward by a gradual process, first through efficient ox-driven implements, then through a small basic tractor to the present type of relatively sophisticated machine in general use today, then the net effect may well

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The nature of the mechanization process in West Pakistan is such that tractor ownership has been concentrated in a small percentage of the landowners. Whereas roughly 92 per cent of the farms with 65 per cent of the total farm area own holdings of less than 25 acres (see Table 2.6), they constitute only 10 per cent of the tractor owners with 9 per cent of the total number of tractors (see Table 2.10). Under West Pakistan conditions, 100 acres is considered to be the optimum size of a farm for a tractor of about 45 horsepower (30). As shown in Table 2.10, 26 per cent of the tractors belong to 29 per cent of the owners with holding sizes of 50 acres and less. It appears that in this category, excluding the joint ownership, there is likely to be a substantial excess tractor capacity. Another 21 per cent tractors on a farm size of 51-100 will also have some excess power. A comparison of the percentage of tractors on different sizes of ownership and operational holdings in Table 2.10 indicates that on small size tractor farms the excess capacity was partly used to increase

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be that they lag further behind as the technology of the developed countries increases their rate of advancement." Furthermore, Giles (23) in his 1967 report to the government of West Pakistan recommended that "It seems inadvisable for West Pakistan to spend precious resources on developing and/or importing the small tractors (5-15 H.P.), except possibly the 7-8 H.P. power tiller for rice. West Pakistan should concentrate on expanding a wide range of large tractors (30-100 H.P.). . . ." As 73 per cent of the total number of tractors were imported during the period 1965-66 to 1968-69, it seems that the recommendations of the World Bank (1966) and Giles (1967) played an important role in influencing the tractor size.

TABLE 2.10.--Percentage Distribution of Tractors and Owners According to Size of Ownership and Operational Holdings.

Size of Holding	Percentage of Tractors and Tractor Owners			
	Ownership Holdings		Operational Holdings	
	Owners	Tractors	Operators	Tractors
0	3	3	1	1
Greater than 0 and less than 13	3	3	1	1
13-25	7	6	4	4
26-50	16	14	15	14
51-100	22	21	27	25
101-200	20	19	26	24
200 and above	29	34	26	31
All holdings	100	100	100	100

Note: Ownership holding refers to the farm land owned, and operational refers to the total farm land operated including both owned and rented.

operational holdings through land renting. Thus, while 29 per cent of the tractor owners owned 50 acres and less, only 21 per cent were operating farms in this size category. On the other hand, 42 per cent owned 51 to 200 acres but 53 per cent had operational holdings in this category. Besides increasing the size of the farm, the tractor owners have also resorted to substantial amounts of custom services. In 1969, of the total area covered by the private tractors, 69 per cent was on self-operated farms and 31 per cent on custom farms (see 50, Table 12).

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Mechanization and the Water Infrastructure

As mentioned earlier, it is the water, rather than the land, which is a constraining factor in West Pakistan's agriculture. If the water constraint is removed, then power could possibly become a binding factor. The mechanization pattern with respect to the water supply system gives some indication of this phenomena. The important factor is that 93 per cent of the tractors are on farms with irrigation. The installation of a tubewell on a canal-irrigated farm provides a very reliable and flexible water supply system and thereby appears to create a demand for more power. Thus, of the total tractors, 63 per cent have been introduced on farms which have both tubewell and canal water available. Another 20 per cent are on the perennial (year round) canal-irrigated farms and 10 per cent on the farms with only tubewell water (see Table 2.11).

TABLE 2.11.--The Percentage Distribution of Tractors with Respect to the Irrigation System, 1968-69.

System of Irrigation	Percentage of Tractors
Canal and tubewell	63
Canals (perennial)	20
Tubewell	10
Others including rainfed	7
Total	100

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Summary

To summarize this chapter: First, it was noted that water is critical for agricultural production in West Pakistan. Due to scarcity of water, the area under cultivation is limited to 48 million acres against 79 million acres available for agricultural purposes. Within the cultivated area itself, production is concentrated in the canal-irrigated areas, especially those having supplementary tubewell water. Secondly, the distribution of land is very skewed. About 49 per cent of the farmers have holdings less than 5 acres and 92 per cent less than 25 acres. The 8 per cent of the farms having land holdings of 25 acres and above have 35 per cent of the total farm area. Furthermore, it was seen that the agriculture sector, with more than 50 per cent of the total labor force in 1970, was the major source of employment. As suppliers of labor, the landless agricultural laborers, constituting about 8 per cent of the total farm labor in 1961, were relatively less important as compared to tenant and owner operators. Tenants play a very significant role in the rural economy. In terms of farm labor supply, the number of farms operated and the farm area, the tenant operators are roughly comparable to owner operators. Lastly, before 1968 government encouraged mechanization through its import, taxation, credit, and other policies. The mechanization pattern emerging in the past showed that the private individual ownership of tractors was dominant and joint and

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and cooperative ownership was relatively insignificant. The tractors were mostly of large sizes with more than three-quarters having 36 horsepower and above. Mechanization was concentrated on irrigated farms, especially on those having both canal and tubewell irrigation. The ownership of tractors was also concentrated on a small number of large farms. About 88 per cent of the tractors were owned by 8 per cent of the farmers having land holdings of 25 acres and above. The tractor use, however, was quite widespread due to custom hiring. A little less than one-third of the total farm tractor use in 1969 occurred on custom farms.

CHAPTER III

DESIGN AND PROCEDURE OF THE SURVEY

Empirical information is essential for an accurate analysis of the effects of the introduction of the tractor. For this reason, a farm management study comparing tractor and non-tractor farms was conducted in the winter of 1972. The author made a field survey among fifty of the larger farmers in the Pakistan Punjab. The purpose was (1) to add additional field evidence to the already existing data on the effects of mechanization and (2) to provide the empirical basis for a linear programming model that could be used to explore the implication of changes in a number of economic parameters whose values are crucial in determining the effect of mechanization.

The strategy of this field survey was to keep the size of the sample small, design it carefully, and conduct the interviews in considerable depth. While this approach sacrifices the averaging effects of a larger sample size, it permits deeper probing into the adjustments and motivations of tractor farmers and the likely long-run consequences of basic alterations in the farming system.

The Design of the Survey

It was obvious at the outset that the effects of tractors would not be uniform across the Punjab. At least three major factors are responsible for this lack of uniformity. First, there are locational differences with respect to the nearest city; second, the cropping patterns differ in different areas due to the soil and climatic conditions; third, the irrigation system is not the same everywhere. In each of these situations, the available choices differ as do the adjustment reactions of the farm firms.

With such a heterogeneous population, the design of the study becomes critical for the accuracy of the results. In designing the survey it was decided to stratify and select typical rural situations, thereby excluding urban influences. To handle the other two sources of heterogeneity, the sample was stratified on the basis of the major cropping patterns and the system of irrigation.

Sample Stratification Based on Irrigation System

Canals are the major source of irrigation water in the Punjab. The canal areas, however, differ with respect to (1) the quality of the underground water and (2) the seasonal distribution of their deliveries. Where the underground water is saline, agriculture is constrained to a fixed supply of canal water. In the sweetwater areas, however, the farmers have removed the water constraint by installing private tubewells. As mentioned earlier, a major portion of the tractors have been introduced in these sweetwater canal areas (see Table 2.11).

Previous studies (48) and our pre-survey field visits indicated that in the sweet ground water canal areas a large number of non-tractor farms with a tubewell hired tractor services; however, in the saline groundwater areas custom work was almost negligible. Thid led to a different composition of the basic sampling unit in the two areas. In the canal plus tubewell areas, the sampling unit included three categories of farms: the tractor-owning farm, the tractor custom farm, and the farm using bullock power only. All farms had their own tubewell. In the case of canal irrigation only, the sampling unit consisted of two farm categories: the tractor owning farm and the farms having bullock power only. Out of the nineteen sampling units, twelve were allocated to the canal plus tubewell and seven to the area irrigated by canal only.

Sample Stratification Based on Cropping Patterns

The part of the sample allocated to the canal plus tubewell area was further stratified on the basis of the cropping pattern. The major winter crop, wheat, is uniformly grown throughout the Punjab and normally covers around one-third of the total cropped acreage.

Cotton and rice are the two major summer crops. Unlike wheat, however, soil and climatic conditions in different districts have considerable impact on the relative area devoted to the two crops. In the districts of Gujranwala, Sialkot, and Sheikhupura, rice is the major summer crop and cotton is relatively insignificant (see Table 3.1). These districts constitute the rice area of

TABLE 3.1.--The Relative Share of Wheat, Cotton, and Rice in the Leading Districts of the Punjab.

District	Crop Area as Per Cent of Total Cropped Area		
	Wheat	Cotton	Rice
Sahiwal	32	14	5
Multan	36	23	1
Lyallpur	38	11	2
Sargodha	36	13	1
Jhang	42	12	1
Rahim Yar Khan	34	25	1
Bahawalpur	34	8	1
Bahawalnagar	27	13	2
Lahore	30	9	5
Gujrat	39	6	8
Sheikhupara	37	6	23
Sialkot	38	2	23
Gujranwala	38	3	26

Source: Pakistan, Ministry of Agriculture and Works, Pakistan Census of Agriculture, 1960, Volume II (October, 1963).

the Punjab. In the districts of Sahiwal, Multan, Lyallpur, Sargodha, Rahim Yar Khan, Bahawalpur, Bahawalnagar, and Jhang, the order is reversed, and cotton dominates as a summer crop. These districts form the cotton area. Out of the twelve sampling units (each consisting of three observations) allocated to the canal plus tubewell area, seven were assigned to the cotton area and five to the rice area.

Pairing of the Sampling Units

Farms owning tractors, hiring tractors, or owning bullocks may obviously differ in many ways other than the use of mechanical power. For example, they may differ in size, the quality of the farm land, the quality of the farm operator, the size and quality of the family labor force, the distance from a metalled (hard surface) road, etc. All these factors have some influence on the profitability of mechanization. In order to identify the influence of tractors from other factors, the different farm categories in the sample unit were paired together with respect to the following:

1. Size of the farm: As it was not considered possible that all farms be of exactly the same size, a range of 25-75 acres was used with a preference for the farms of around 50 acres.

2. Quality of farm land: All farm categories should have a comparable farm land quality.

The Survey Procedure

After reviewing the previous literature on mechanization, a detailed questionnaire was prepared while the author was in the United States. Consultations with the members of the thesis committee at Michigan State University led to considerable modification of the questionnaire. Some further modifications were made after the questionnaire was pre-tested in the Punjab. A copy of the final questionnaire used for recording the answers of the respondents is attached as Appendix B. The author conducted the field survey in the Punjab from October, 1971, to March, 1972. Despite the problems of recall, the questionnaire was designed to ask questions about the Kharif (summer) crops of 1971 that were harvested from October to December and the preceding Rabi crops of 1970-71 harvested in April, 1971. This strategy permitted the recording of a full year of agricultural activity while ensuring the best recall possible under the given circumstance.

Selection of the Districts

The first step in initiating the field survey was to select districts that would represent each of the conditions previously described. An additional criterion for choosing a district was the size of the tractor population. Other minor considerations were their distances from each other and their accessibility from the cities of Lahore and Lyallpur where the author was stationed during the survey period.

Table 3.2 gives the ranking of the eleven leading districts in terms of the private tractor population. On the basis of their tractor population ranking, the districts of Sahiwal and Gujranwala were selected in the cotton and rice areas, respectively. A third district was to be selected that would have tractor farms having no tubewells. At the time of the questionnaire pre-testing, it was found that where underground water was sweet, it was not possible to find a tractor farm without a tubewell. The tubewell comes first or simultaneously with the tractor. This situation exists in most of the rice area. It was only in areas where underground water was saline that one could find tractor farms without a tubewell. Lyallpur district, which has saline water in most parts and ranks fourth in the tractor population, was chosen for the non-tubewell case.

Selection of the Sample Units

In the selected districts, the first point of contact was the agriculture officer in charge of the district. Designated as the Extra Assistant Director of Agriculture, he was approached through the Secretary of Agriculture, Government of the Punjab. The objectives of the research and the design of the survey were explained to the Agriculture Officer, and with his consultations

TABLE 3.2.--Ranking of the Punjab Districts by the Number of Private Tractors in 1969.

District	Ranking Within the Cotton or Rice Area		Overall Ranking
	Cotton Area	Rice Area	
Sahiwal	1		1
Multan	2		2
Lahore	3		3
Lyallpur	4		4
Sargodha	5		5
Rahim Yar Khan	6		6
Jhang	7		9
Bahawalnagar	8		10
Gujranwala		1	7
Sheikhupura		2	8
Sialkot		3	11

Note: Ranking of a district as 1 indicates that the number of tractors are largest there as compared to other districts.

Source: Pakistan, Ministry of Agriculture and Works, Agriculture Census Organization, Farm Mechanization in West Pakistan (Islamabad, June, 1969).

the suitable area in the district was identified. The major consideration here was that the sample area, besides fulfilling other conditions, should be far away from the district Headquarters, sugar mills, and the centers of major construction activity. Thus, the next step was to move to a distant small Mandi Town and contact the local agriculture extension worker designated as the Agriculture Assistant. The Agriculture Assistants maintain a record of the number of tractor owners in their area. In some instances, they also have a record of the farm size. However, no records are kept on the bullock farms and on the farms hiring tractor services.

After locating the tractor farms, the survey was begun, with the expectation that the custom and bullock farms would also be found in the same villages along with the tractor farms. This proved to be true in the case of Lyallpur district, but in the districts of Sahiwal and Gujranawala it was found that, while the custom farms were very common, it was not easy to find a bullock farm in the specified farm size range. This prompted a reversal of strategy; through extensive tours, the author first searched for bullock farms and, after their identification, looked around them for tractor and custom farms. This proved more successful, and with the sample unit identified in this way, the survey was started.

While locating sample units, considerable care was taken to be sure that the sample farms were away from the even small Mandi towns. This insured a cropping pattern that was typically rural with no sign of town proximity in terms of growing vegetables and fodder for sale. The sample farms were also checked to be sure that they were within the farm size range specified earlier. However, the questions about the quality of the farm land and the farm operator were asked after reaching the sample village. Considerable reliance was placed on the judgments of local landowners regarding comparability of soil and drainage characteristics of various holdings. With respect to the quality of the farm land, it was found that there were vast stretches of land of uniform quality in the Chickawatni area of the Sahiwal district and so no problem was faced. But in the districts of Lyallpur and especially the Gujranwala, the quality of land in some cases differed even in the same village, depending on which side of the village the farm was located. In the Lyallpur district where the water supply is dependent on the canal system only, the water availability was not uniform. Two farms may be on the same water course, but still the water available could differ depending on whether the farm is located in the beginning or end of the water course. Due to non-comparability of the farm land quality in the Lyallpur and the Gujranwala and the water supply in the

Lyallpur district, it was necessary to drop a few sample units from the initial list. These were replaced by new observations in the field.

Regarding quality of the farm operator, it was observed that the excellent and the poor were very few and the majority belong in between. However, in a few cases it was necessary to drop the sample unit from the list because of non-comparability of the farm operators.

Interviewers and Interviewees

As originally planned, Agriculture Assistants were to be hired to conduct the interviews. For this purpose, three of them were given training. However, as the writer gained more experience with the field situation--initially through pre-testing of the questionnaire and later through the selection of the sample units--he became convinced that the survey questionnaire had become so complex that it would not be advisable to entrust the data collection to the hired interviewers. Except for two sampling units interviewed in his presence, the rest were interviewed by the author.

Another factor affecting this decision was that the interviewees appeared much more suspicious of the government officials. The author introduced himself as a student and one belonging to a farm family (which he is) which appeared to lessen the farmers' suspicion. The most

important factor in this respect, however, was the use by the author of his rural social contacts.

Summary

A total of fifty interviews were completed in the survey, and the sample was stratified to take account of different systems of irrigation and cropping patterns in the Punjab. Out of the fifty interviews, fourteen were among farms having canal irrigation only and thirty-six were among farms having both canal and tubewell. The latter were further sub-divided to allocate 21 and 15 to the wheat-cotton and wheat-rice cropping areas, respectively. Considerable care was taken to standardize as much as possible all aspects of the units sampled, save those items which actually bear on the mechanization question. For example, it will be noted in Table 3.3 that the mean value of all categories of farms is approximately the same. Moreover when a tractor farmer was selected for interview, the corresponding traditional bullock farm was selected to reflect conditions in the same village, essentially the same soil, a similar position on the water course, etc. The result is a sample that is not random in its selection but one in to which a good deal of effort has gone to isolate mechanization as the major causal difference in the observed data between tractor farms and the traditional bullock farms.

TABLE 3.3.--Farm Management Survey of Tractor and Bullock Farmers in the Pakistan Punjab.

	Lyallpur		Sahiwal		Gujranwalla	
	Canal Water Only		Canal Plus Tubewell Water		Canal Plus Tube-well Water	
	Wheat - Cotton		Wheat - Cotton		Wheat - Rice	
	Number	Mean Size	Number	Mean Size	Number	Mean Size
Bullock Farms	7	39.0	7	43.5	5	47.6
Tractor Hire Farms			7	41.6	5	43.0
Tractor Farms	7	41.1	7	45.3	5	41.0

CHAPTER IV

THE OUTPUT AND SOCIAL EFFECTS OF TRACTOR MECHANIZATION IN THE PAKISTAN PUNJAB

This chapter presents the results of the survey of farmers in the Punjab in two parts. The first section presents and analyzes output data relevant to the question of direct costs and benefits of mechanization. Section two is devoted to a discussion of the social implications of mechanization, i.e., its influence on farm employment, and land tenure conditions.

Output Effects

The output effects of mechanization can be divided into three parts: (1) effects on cropping intensity, (2) effects on yields, and (3) effects on cropping patterns. Before and after comparisons will be based on a cross-sectional comparison of the machanized and non-mechanized farms.

Cropping Intensities

The most forceful argument advanced in support of mechanization is based on the contention that mechanical power, by speeding up the farm operations, permits multiple cropping and, therefore, higher agricultural production from a given land area than would be possible with the slow moving bullocks. In this section the empirical evidence on cropping intensities as it emerged from the survey data is presented. Table 4.1 presents a detailed comparative picture of the cropping intensities for the farms surveyed, by categories.

Cropping Intensities in Non-Tubewell and Tubewell Canal Irrigated Areas

It will be obvious from Table 4.1 that tractor mechanization has made little difference in cropping intensities in the non-tubewell areas. The intensity on mechanized farms was 109 per cent as opposed to 112 per cent of the bullock farms. The saline groundwater rules out the possibility of pumping supplementary tubewell water in this area. Sole dependence on canal water in a low rainfall area results in a water constrained farming system. The power and the speed provided by the tractor does not help to increase the cropping intensity since timeliness in removing one crop to plant another is of little value.

TABLE 4.1.--Cropping Intensities on Different Types of Farms in Tubewell and the Non-Tubewell, Canal Irrigated Areas.

	Tubewell Area (Canal Plus Tubewell)									Non-Tubewell (Canal Only)	
	Cotton Zone			Rice Zone			Total				
	Tractor Operated	Tractor Custom	Bullock Operated	Tractor Operated	Tractor Custom	Bullock Operated	Tractor Operated	Tractor Custom	Bullock Operated	Tractor Operated	Bullock Operated
Total Cultivated Area (Acres)	317.00	291.00	304.50	205.00	215.00	238.00	522.00	506.00	542.50	264.50	273.00
Total Cropped Acreage	514.10	418.19	393.25	362.75	396.75	386.12	876.85	814.94	779.37	287.76	307.15
Cropping Intensity[a]	162.2	143.7	129.1	176.9	184.5	162.2	168.0	161.0	143.6	108.8	112.5
Average Size of Farm (Acres)	45.3	41.6	43.5	41.0	43.0	47.6	43.5	42.2	45.2	37.8	39.0

[a]Cropping intensity = $\frac{\text{Total Cropped Acreage}}{\text{Total Cultivated Acreage}} \times 100$. The area under the annual crop of sugar cane is counted twice in the total cropped acreage.

The situation is markedly different in the sweet groundwater area. Here tubewells provide supplementary water in addition to that available from the canal, thus removing or reducing the water constraint. Even on the farms having only bullock power, the intensity increased to 143.6 per cent. The availability of tractor power further increased the intensity to 168 per cent on farms having their own tractors and to 161 per cent on the farms hiring tractor services. These results indicate the importance to the farming system of the water supply in determining the output effects of mechanization through multiple cropping. With the limited canal supplies in the non-tubewell areas, water rather than power appears to be the constraining factor. Once the water limitation is overcome, the cropping intensities can often be increased up to a point.

As Table 4.1 indicates, increased intensities occurred even with the existing bullock power. In part, the increase in intensity is due to the overall increase in water supplied. However, it was also a response to the removal of the rigidities of canal water deliveries. When water is limited to canal deliveries, temporal rigidities occur in the farm operations that produce a bunching up of activities around canal turns. The flexibility of the tubewell water breaks up these rigidities in the farm operations and allows their spreading out over time, therefore allowing a more regular use of the bullock power. This is particularly apparent on the bullock farms in the cotton zone of the tubewell area where with 29 per cent less bullock power, a higher intensity was achieved than on the bullock farms in the non-tubewell area (Table 4.1).

The data suggest, however, that where tubewell water is supplementing canal water, power does become the limiting factor. At least tractor farmers have attained a substantially higher intensity than bullock farmers.

In the tubewell area, the farms hiring tractor services have also attained higher crop acreage per unit of cultivated area. With their cropping intensity of 161 per cent, they were very close to the level of 168 per cent on the tractor farms. This explains the widespread tractor hiring market that has developed in the tubewell area. In the non-tubewell area, on the other hand, tractor hiring for crop cultivation purposes was almost non-existant. Indeed, by implication, this finding suggests that mechanization in the non-tubewell areas is proceeding from at least partially different motivations than those underlying the investment decisions in the tubewell areas. (This point will be investigated further in the programming models where rates of return for the two areas are presented.)

Cropping Intensities in Cotton and Rice Zones

Within the tubewell area, the influence of mechanization on the cropping intensities differs considerably with the cropping pattern. In the first place, the absolute level of intensities on all types of farms in the cotton zone was lower than in the rice zone. An interesting aspect of this difference is that the bullock farms in the rice zone have achieved a level of cropping intensity equivalent to that of the tractor farms in the cotton zone. Secondly, the difference between the intensities on the mechanized and the non-mechanized farms was greater in the cotton zone than in the rice zone. In the cotton zone, the mechanized farms had an intensity of 162 per cent as compared to 129 per cent on the bullock farms. The tractor hiring farms were in between with an intensity level of 144 per cent. In the rice zone, the tractor hiring farms achieved the highest intensities, i.e., 184 per cent, and the tractor farms had 177 per cent as compared to 162 per cent on the bullock farms.

Why did the intensities differ in the two zones, both before and after mechanization? An answer to this question requires a more detailed investigation of the interaction between cropping patterns and intensities as found in the survey data. For example, Table 4.2 gives the cropping pattern as found on bullock farms in the cotton and rice areas.

TABLE 4.2.--The Percentage Share of Different Rabi (Winter Season) and Kharif (Summer Season) Crops in the Total Cropped Area on Bullock Farms in the Cotton and the Rice Zones during 1970-71.

					Cotton Zone				
	Crops	Wheat	Fodder	Gram	Toria	Fruits and Vegetables	Tobacco	Miscel-laneous	Total Rabi
Rabi 1970-1971	% Share	36.58	8.33	0.46	0.46	0.52	0.52	0.26	47.13
	Crops	Cotton	Fodder	Maize	Rice	Fruits and Vegetables	Sugar-Cane	Miscel-laneous	Total Kharif
Kharif 1970	% Share	34.37	11.46	1.82	2.60	0.21	2.41	. .	52.87
Total									100.00
					Rice Zone				
	Crops	Wheat	Fodder	Gram	Toria	Fruits and Vegetables	Tabacco	Miscel-laneous	Total Rabi
Rabi 1970-1971	% Share	35.26	10.65	0.79	1.45	0.13	0.13	0.26	48.67
	Crops	Cotton	Fodder	Maize	Rice	Fruits and Vegetables	Sugar-Cane	Miscel-laneous	Total Kharif
Kharif 1970	% Share	0.39	9.21	. .	39.99	0.16	1.58		51.33
Total									100.00

The data in Table 4.2 shows that the cropping pattern in both the zones is dominated by two major crops, one each in the rabi (winter) and the kharif (summer) season. In the cotton zone, wheat and cotton are the major rabi and kharif crops, respectively. Together they contributed about 71 per cent of the total cropped acreage during the year (wheat, 36.6 per cent; cotton, 34.4 per cent). In the rice zone, on the other hand, the major summer crop is rice which together with wheat contributed about 75 per cent of the total cropped acreage (rice, 40 per cent; wheat, 35 per cent).

As these figures indicate, without the introduction of a major new crop or a considerable increase in diversification, increases in cropping intensity depend on the possibility of wheat and cotton following each other in the cotton zone and a wheat-rice sequence in the rice zone. In the tubewell area where water is no constraint, these possibilities will be determined to a large extent by the sowing and harvesting calender of the two crops in the two zones, their power requirements for these operations, and the power that is available. Table 4.3 presents the sowing and the harvesting calendar for wheat, cotton and rice.

It is clear from the crop calendar that farmers in the rice zone face a different situation with respect to multiple cropping than those located in the cotton

TABLE 4.3.--The Sowing and Harvest Calendar for Wheat, Cotton, and Rice in the Punjab.

Crops	Months						
	April	May	June	July	October	November	December
Cotton	Sowing					Harvesting of April Sowing	Completed of May Sowing
Wheat	Field Cutting	Processing requiring bullocks or tractors or threshers			Desi Variables	Improved Varieties	
Rice			Sowing New Variety	Desi Basmati		Harvesting New Desi	

area. In the wheat-cotton case, the harvesting of wheat and sowing of cotton overlap. Traditionally the farmers have handled this problem through late sowing of cotton. But the late sowing of cotton (late May or early June) delays the cotton harvest to December and so overlaps with wheat sowing. This clash has been the most serious, and historically very little wheat has followed cotton. (However, the new late-sowing varieties of wheat have lessened the extent of the overlap and are opening up new possibilities for increasing intensity.)

With the wheat and rice sequence, there is almost no overlapping of the sowing and harvest periods of the two crops. The sowing of the rice starts after the harvesting of the wheat is over. In the fall, the rice harvest time and the wheat sowing are close but the new early-maturing rice varieties and the new late-sowing wheat varieties have increased significantly the time between the rice harvesting and wheat sowing. Thus, in the rice zone most of the rice and the wheat follow each other. This explains the higher level of cropping intensities on all types of farms in the rice zone compared to those obtained in the cotton zone.

Because the question of overlapping crop sequence is a crucial parameter in efforts to explore the benefits of mechanization, it is instructive to examine the crop rotations prevailing in the two areas in more detail.

Tables 4.4 and 4.5 give an account of the crop rotations with respect to the major _rabi_ and _kharif_ crops.

As is evident from Table 4.4, most of the rice and wheat in the rice zone follow each other and the previous season fodder. The percentage of the two crops following the previous season crops was higher on the mechanized farms, which had 92 per cent of their wheat and 100 per cent of the rice after other crops. Thus, the multiple cropping possibilities have been substantially realized in the rice area by the mechanized farms with the bullock farms following closely.

The situation was different in the cotton zone. On both the mechanized and the bullock farms, cotton mainly followed wheat. But most of the wheat did not follow cotton. About 71 and 86 per cent of the cotton on the mechanized and the bullock farms respectively followed wheat, but only about 14 per cent of the wheat followed cotton.

Comparison of the cropping intensities on the mechanized and the bullock farms in the context of their respective crop rotations can be used to examine the extent to which the double cropping potential has been exploited by mechanized and bullock farms. Table 4.6 is an abstract derived from the cotton zone crop rotation data given above.

TABLE 4.4.--Crop Rotations in the Rice Zone in the Punjab.

Crops	Farm Type	Total Farm Area (Acres)	Area Sown				
			Total (Acres)	After Fallow (%)	Percentage After the Preceding Season Crops		
					Total	After Rice	After Fodder
Wheat Rabi 1970-71	Tractor Farms	205 (200)	154.5 (150.7)	7.8	92.2	85.4	6.8
	Bullock Farms	238 (200)	134.0 (112.6)	12	88	83.5	4.5
					Total	After Wheat	After Fodder
Rice Kharif 1971	Tractor Farms	205 (200)	141.5 (138)	. .	100	96.5	3.5
	Bullock Farms	238 (200)	152 (127.7)	6.6	93.4	79.6	13.8

TABLE 4.5.--Crop Rotations in the Cotton Zone in the Punjab.

Crops	Farm Type	Total Farm Area (Acres)	Area Sown				
					Percentage After the Preceding Season Crops		
			Total (Acres)	After Fallow (%)	Total	After Cotton	After Maize, Rice, Fodder, etc.
Wheat Rabi 1970-71	Tractor Farms	317.0 (300.0)	173 (163.7)	54.6	45.4	14.7	30.7
	Bullock Farms	304.5 (300.0)	140.5 (138.4)	62	38	13.5	24.5
					Total	After Wheat	After Fodder
Cotton Kharif 1971	Tractor Farms	317.0 (300)	136.75 (129.4)	15	85	71.3	13.7
	Bullock Farms	304.5 (300)	132 (130)	3.8	96.2	86.4	9.8

TABLE 4.6.--Crop Rotations on Cotton Zone Farms (Summary).

	Tractor Farms	Bullock Farms
Winter Wheat (1970)	163.7 acres	138.4 acres
Cotton (1971)	129.4 acres	130.0 acres
Percentage of Cotton Following Fallow	15 per cent	3.8 per cent
Percentage of Cotton After Wheat and Other Crops	85 per cent	96.2 per cent

The data show that on a comparable farm size, the tractor farms had a wheat acreage of about 164 acres as compared to 138 acres on the bullock farms. With this higher wheat land and the tractor power, it would appear that the mechanized farms could have brought in a greater area under cotton. But this was not done. Indeed, the cotton area on two types of farms was the same. The tractor farms grew 85 per cent of their cotton after wheat and other crops, against 96 per cent on the bullock farms. Thus, in respect to the summer crop of cotton, the mechanized farms have not exploited the greater potential of double cropping available to them as compared to the bullock farms.

In the case of wheat on tractor farms, 45 per cent came after the previous season crops as compared to 38 per cent for bullock farms. The higher wheat acreage has made and important contribution to the higher cropping intensities on the mechanized farms, which however, have not yet achieved any breakthrough in exploiting the multiple cropping potentiality of bringing wheat after cotton. In the case of mechanized farms, 14.7 per cent of their wheat followed cotton as compared to 13.5 per cent on the bullock farms. The higher wheat acreage on the mechanized farms had been achieved mainly through the traditional cropping sequence, i.e., wheat following maize, kharif fodder, rice, etc., rather than using tractor speed and power to bring wheat after cotton.

The realization of the latter possibility will, in most cases, require removing the cotton crop earlier and doing the last picking on the removed stalks. (Most of the tractor owners believed in giving rest to the land and were not prepared, though capable, to adopt this "unconventional" practice.)

Yields Per Acre

Besides the cropping intensity effects, yield per acre is another variable through which mechanization can influence the agricultural production. In this section, data is presented on the yields of the major crops on the mechanized versus bullock farms in the different survey areas. The discussion is again confined largely to the major crops: wheat, rice, and cotton.

Table 4.7 presents average yields per acre as reported by the survey respondents. The data shows that

TABLE 4.7.--Yields on the Tractor and the Bullock Farms in Various Areas.

Crops	Sweet Water Area						Saline Water Area		
	Cotton Zone			Rice Zone			Cotton Zone		
	Tractor (mds.)	Bullock (mds.)	Difference[a] (%) (Tractor-Bullock)	Tractor (mds.)	Bullock (mds.)	Difference[a] (%) (Tractor-Bullock)	Tractor (mds.)	Bullock (mds.)	Difference[a] (%) (Tractor-Bullock)
Wheat	29.2	33.5	-12.8	22.9	17.1	+33.9	30.0	30.0	. .
Cotton	12.2	14.1	-13.5	. .	. .	. .	12.3	10.8	+13.9
Rice	. .	. .	. .	16.4	19.4	-15.5	. .	. .	. .
Sugar-cane	40.0	40.0	. .	33.6	30.8	+9.0	60.7	58.6	+3.6
Toria	. .	. .	. .	. .	. .	. .	12.3	13.3	-7.5

[a]Difference measured from bullock farmer base.

in the cotton area, the bullock farms had substantially higher yields than tractor farms in both wheat and cotton and similar yields in sugarcane. In the rice zone, bullock farms had higher yields in rice but substantially less in wheat and sugarcane.

In the non-tubewell area, wheat yields exhibited little difference, but tractor farms had higher yields in cotton and sugarcane. Bullock farms, on the other hand, had higher yields in toria (oilseeds).

The general conclusion that emerges from the above data is that while yields did differ between mechanized and non-mechanized farms, there was no consistency in the direction of the difference. This finding appears to run counter to a number of researchers who have agreed that the effect of mechanical tillage is (1) to produce a better seed bed and thus to insure higher germination and more vigorous plants, and (2) to permit a more optimal planting schedule. However, before declaring the above hypotheses refuted, it should be emphasized that realized yields per acre are a result of a number of interacting factors: the quality of the land preparation, the sowing date, the sowing method, the seed variety, the quantity of fertilizer, the extent of the hoeing and weeding, the proficiency of water management, etc. Any or all of these could very well account for the differences in observed yields indicated earlier.

The following paragraphs examine more closely the survey results in an attempt to isolate further the sources of the yield differences noted in Table 4.7.

Tractor Implements and Equipment

A total of nineteen tractor farm owners were asked about the tractor-drawn implements and equipment they owned. The information received is summarized in Table 4.8.

TABLE 4.8.--Tractors and Equipment on Nineteen Mechanized Farms Surveyed.

Tractors and Equipment	Survey of Nineteen Tractor Farms by the Author	Survey of 17,123 Tractor Farms by the Pakistan Agricultural Census Organization
Tractors	19	17,123
Cultivators	19	14,338
Disc Harrow	. .	2,007
Mould Board and Disc Plow	. .	4,848
Row Crop Planters	. .	169
Grain Drills	1	563
Fertilizer Distributors	. .	88
Trailers and Wagons	14	6,962

From the standpoint of understanding yield differences, it is important to note that none of the tractors was equipped with implements such as the mould board or disc plow needed for deep preparatory tillage. All of them had cultivators largely designed for intertillage but in practice also used for the preparatory tillage. The cultivators normally plow 4" - 5", deep which is also the traditional depth reached by the bullock drawn plow (64, p. 82). Regarding sowing equipment, of the nineteen tractor owners, only one had a grain drill, none had row crop planters for rabi crops. Also, there were no fertilizer attachments among any of the nineteen farmers. These findings are corroborated by a larger survey conducted by the Pakistan Agriculture Census organization which shows that, on the whole, the implements and equipment for preparatory tillage and fertilizing were very limited as compared to the number of tractors. It seems that most of the equipment was purchased by the very large farmers, and almost none was being used on farm sizes below 100 acres.

Given this tractor equipment package, there is little reason to believe that the mechanized farms had a better land preparation or sowing methods than the bullock farms. Timeliness of sowing might have been improved somewhat in the areas where supplementary water made a high cropping intensity possible, but there was apparently not enough difference to influence yields significantly.

Agricultural Inputs and Practices

This section presents the analysis of the inputs by major crops in each survey area.

Wheat-Cotton Area (Canal Plus Tubewell Water).--The input and improved practices data for wheat and cotton shown in Table 4.9 can be analyzed as follows:

Wheat: As shown earlier (Table 4.7) bullock farms showed yields that were 13 per cent higher than those obtained on tractor farms. In terms of inputs, they exhibited the following characteristics when compared to tractor farms (see Table 4.9): higher percentage of the crop following fallow land, higher percentage using the recommended row sowing technique (66% per cent versus 18%), considerably higher water-course cleaning intensity, and lower fertilizer use per acre (64 versus 74 nutrient pounds).

Cotton: Bullock farms with 13.5 per cent higher yield, as compared to the tractor farms, used a different package of inputs. They had a larger percentage of crop area under row sowing (29 versus 12) and higher water-course cleaning intensity but less hoeing and a lower quantity of fertilizer per acre (58 versus 71 nutrient pounds).

TABLE 4.9.--Level of Inputs and Improved Practices.

Inputs and Improved Practices	Farm Type	Wheat	Cotton
Average Plowings per Acre	Tractor	8	5.0
	Bullock	8	5.3
Per cent of the Crop on Fallow Land	Tractor	55	15.0
	Bullock	62	3.8
Fertilizer (Nutrient Pounds per Acre)	Tractor	74	71
	Bullock	64	58
Seed Variety (Per cent Under Improved Variety)	Tractor	93	. .
	Bullock	94	. .
Sowing Method (Per cent Under Row Sowing)	Tractor	18	12
	Bullock	66	29
Hoeing (Per cent of the Crop Covered)	Tractor	. .	66
	Bullock	. .	53
Water Course Cleaning (Intensity per Acre)	Tractor	1.7	2.5
	Bullock	3.9	3.1
Thinning (Intensity per Acre)	Tractor	. .	1.2
	Bullock	. .	1.1

Wheat-Rice Area (Canal Plus Tubewell Water.--According to the information in Table 4.10 for the wheat-rice area, the tractor farms had 33.9 per cent higher yield in wheat, while the bullock farms had 15.5 per cent higher yield in rice. To a great extent, the special characteristics of rice and wheat cultivation in this area explain the difference in yield. The technique of land preparation for rice crop requires plowing and planking in the flooded fields several times. This practice hardens the soil crust and helps to hold the water and keep it standing longer in the field throughout the crop season, which, in turn has a favorable effect on the yield. The tractor farms do not possess the necessary equipment for land preparation under the standing water. The bullock farms with more bullock power (see Table 4.15) and family labor have an advantage in land preparation for rice. But the hard crust of soil which helps to increase the rice yield becomes a problem for the bullock farms when they prepare that land for wheat. (About 84 per cent of their wheat follows rice. See Table 4.5.) That hard crust is difficult to break with bullock power. Here tractor owners have an advantage and achieve a better quality of land preparation for wheat which makes an important contribution to increasing the wheat yields.[1] Against

[1]The bullocks kept by the tractor owners are not used for wheat but are used mainly for rice cultivation (see Table 4.17).

TABLE 4.10.--Input Level and Improved Practices.

Inputs and Improved Practices	Farm Type	Wheat	Rice
Average Plowings per Acre	Tractor	6.5	8.9
	Bullock	7.4	9.3
Per cent of the Crop on Fallow Land	Tractor	7.8	. .
	Bullock	11.9	6.6
Fertilizer (Nutrient Pounds per Acre)	Tractor	64	10.6
	Bullock	48	12.0
Seed Variety (Per cent Under Improved Variety)	Tractor	100	16
	Bullock	100	31
Sowing Method (Per cent Under Row Sowing/Transplant)	Tractor	. .	100
	Bullock	1.5	100
Weeding (Per cent of the Crop Covered)	Tractor	. .	21
	Bullock	. .	23
Water-Course Cleaning (Intensity per Acre)	Tractor	1.9	3.5
	Bullock	1.5	3.5

this general background of some of the special characteristics of the area which favor particular technology in particular crops, the comparative position of the input use on tractor as compared to bullock farms was as follows:

Wheat: Tractor farms had higher fertilizer input per acre (64 versus 48 nutrient pounds) and somewhat better water-course cleaning. Bullock farms, on the other hand, had somewhat higher crop area on fallow land (11.9 versus 7.8 per cent) and a slightly better sowing method.

Rice: Bullock farms had a higher percentage of the crop following fallow land, slightly higher fertilizer input per acre, and better weeding operation as compared to tractor farms. The sowing method was comparable on both--each having 100 per cent transplanted rice crop.

Wheat-Cotton Area (Canal Water Only).--The input and improved practices data for wheat and cotton in areas of canal water only are shown in Table 4.11 and analyzed below in relation to their average yields given earlier:

Wheat: Tractor farms showing the same yield per acre as bullock farms had a comparable sowing method, higher fertilizer input (90 versus 73 nutrient pounds per acre), and lesser crop area on fallow land (82 versus 91 per cent) as compared to bullock farms.

Cotton: The yield per acre was about 14 per cent higher on tractor as compared to bullock farms. Regarding the use of inputs, tractor farms had a higher percentage of the crop following fallow land (27 versus 10 per cent), higher fertilizer input per acre (107 versus 88 nutrient pounds), and higher thinning intensity per acre as compared to bullock farms. Bullock farms, on the other hand, had a higher percentage under row sowing (87 versus 55) and a higher hoeing intensity.

TABLE 4.11.--Level of Inputs and Improved Practices.

Inputs and Improved Practices	Farm Type	Wheat	Cotton
Average Plowings Per Acre	Tractor	9.2	5.4
	Bullock	7.9	7.2
Per cent of the Crop Following Fallow Land	Tractor	81.6	26.7
	Bullock	90.5	9.8
Fertilizer (Nutrient Pounds per Acre)	Tractor	90.0	107
	Bullock	72.5	88
Seed Variety (Per cent Under Improved Variety)	Tractor	100	. .
	Bullock	97	. .
Sowing Method (Per cent Under Row Sowing)	Tractor	70	55
	Bullock	69	83
Hoeing (Per cent of the Crop Covered	Tractor	. .	49
	Bullock	. .	86
Water Course Cleaning (Intensity Per Acre)	Tractor	2.5	0.5
	Bullock	2.7	1.4
Thinning (Intensity Per Acre)	Tractor	. .	1.3
	Bullock	. .	0.8

The major conclusion that emerges from the analysis in the preceding paragraphs is that on the mechanized farms, the tractor has not been accompanied by a simultaneous increase in the bundle of inputs and improved practices. Table 4.12 aggregates the previous area-wise findings and shows that the mechanized farms, on the average, used about 61 nutrient pounds of fertilizer per acre as compared to about 51 pounds used by the bullock farms. In other practices, however, the bullock farms compared favorably. They had as much or more of their wheat and rice in improved varieties, better sowing practices, more weeding and hoeing, etc. This suggests that the tractor has not served, at least not yet, as a "catalyst" for modernization as suggested by Johl (36). Tractor farmers used slightly more of the off-farm purchased input of the chemical fertilizers but hardly enough to be significant. As a result, the bullock farms have not, on the whole, lagged behind in yield.

This information on the tractor equipment, agricultural inputs, and practices leads to the conclusion that technological change in the Punjab agriculture is not appearing in the form of a complete "package" of inputs. Farmers have picked up the most outstanding inputs and have either ignored associated inputs and practices or kept them at well below recommended levels. The mechanized farms, for example, have purchased the tractor but not the

TABLE 4.12.--Aggregate Input Levels and Improved Practices by Crop.

Imports	Farm Type	Wheat	Cotton	Rice	All Crops
Fertilizer (Pounds of N per Acre)	Tractor	69.5	80.5	10.6	61.3
	Bullocks	60.0	64.4	12.0	50.9
Seed Variety (Crop Percentage Under Improved Variety)	Tractor	97.2	. .	16.0	77.5
	Bullocks	97.1	. .	31.0	78.7
Sowing Method (Crop Percentage Under Row Sowing/ Transplant)	Tractor	25.4	23.7	100.0	38.7
	Bullocks	45.3	40.8	100.0	55.7
Weeding/Hoeing (Percentage of the Crop Covered)	Tractor	. .	61.5	21.0	44
	Bullocks	. .	71.4	23.0	48.4
Water-Course Cleaning (Intensity per Acre)	Tractor	2.0	2.6	3.5	2.3
	Bullocks	2.9	2.9	3.5	3.0
Thinning (Intensity per Acre)	Tractor		1.2		1.2
	Bullocks		1.0		1.0

necessary equipment for deep ploughing, row sowing, and fertilizing.[1] Similarly, they have adopted the high yielding varieties of wheat but not the associated practices. During the 1970-71 season, the mechanized farms covered 97 per cent of their wheat land with improved varieties but used only 69.5 nutrient pounds per acre against the recommended dose of 140 pounds[2] and covered only one-fourth with row cropping[3] (see Table 4.13). Some of the results of an earlier study (24) on tubewells lends further support to this hypothesis. Their results indicated that the methods of cultivation and the type of implements used did not change after the tubewell--the most outstanding input of the package.

Cropping Pattern Effects

Theoretically, in addition to increases in cropping intensity and improvement in yields, mechanization could

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[1]Discussion between the author and the concerned experts in the Punjab Agriculture Department indicated that they believe the lack of the perception of the benefits of equipment and finances are the reasons why farmers were not purchasing this equipment.

[2]For an average soil the Department of Agriculture recommends 90 pounds of nitrogen and 50 pounds of phosphorous (see 54, p. 84). The 69.5 pounds actually used by the farmers contained less than 20 per cent of phosphorous.

[3]This conclusion is corroborated by another study in the Punjab by Lowdermilk (see 62).

TABLE 4.13.--Cropping Pattern on Different Types of Farms in Different Areas.

Crops	Tractor Farms Per cent of the Total Cropped Area	Bullock Farms Per cent of the Total Cropped Area
A. Cotton Zone (Canal Plus Tubewell Water)		
Rabi (Winter Season)		
Wheat	34.44	36.58
Fodder	5.97	8.33
Gram	0.55	0.46
Toria	1.20	0.46
Fruits and Vegetables	5.08	0.52
Tobacco	1.57	0.52
Miscellaneous	3.19	0.26
Rabi Total	52.00	47.13
Kharif (Summer Season)		
Cotton	27.22	34.37
Fodder	7.81	11.46
Maize	4.18	1.82
Rice	1.14	2.60
Sugarcane	2.34	2.41
Fruits and Vegetables	5.21	0.21
Miscellaneous	0.1	. .
Kharif Total	48.00	52.87
Grand Total	100.00	100.00
B. Rice Zone (Canal Plus Tubewell Water)		
Rabi (Winter Season)		
Wheat	42.98	35.26
Fodder	7.23	10.65
Gram	0.35	0.79
Toria	0.35	1.45
Fruits and Vegetables	0.12	0.13
Tobacco	0.29	0.13
Miscellaneous		0.26
Rabi Total	51.32	48.67
Kharif (Summer Season)		
Cotton	0.28	0.39
Fodder	7.65	9.21
Maize	. .	. .
Rice	39.36	39.99
Sugarcane	0.90	1.58
Fruits and Vegetables	0.35	0.16
Miscellaneous	0.14	. .
Kharif Total	48.68	51.33
Grand Total	100.00	100.00
C. Lyallpur Area (Canal Water Only)		
Rabi (Winter Season)		
Wheat	43.31	43.17
Fodder	6.64	5.91
Gram	2.47	3.40
Toria	6.64	8.33
Fruits and Vegetables	0.02	0.02
Tobacco	0.47	0.34
Miscellaneous	0.94	0.54
Rabi Total	60.49	61.71
Kharif (Summer Season)		
Cotton	18.24	12.81
Fodder	6.27	6.63
Maize	4.30	4.83
Rice	. .	. .
Sugarcane	7.67	10.03
Fruits and Vegetables	0.97	2.20
Miscellaneous	2.06	1.79
Kharif Total	39.51	38.29
Grand Total	100.00	100.00

contribute to the gross value product by changing the cropping patterns. First, the replacement of the bullocks by the tractor would release the fodder cropped area for the production of other crops. Secondly, some high value crops might be substituted for the low value crops if such a substitution was otherwise profitable but was constrained due to lack of power. Table 4.13 gives the comparative cropping patterns of the mechanized and the non-mechanized farms in different survey areas.

As would be expected, the tubewell and the non-tubewell areas differed in the proportion of the total annual crop acreage sown in the winter and the summer seasons. The share of the Rabi (winter season) crops varied from 47 to 52 per cent in the former against 60 to 62 per cent in the latter. Due to water constraint in the non-tubewell area, both mechanized and bullock farms grew a higher proportion of their annual crop acreage during the winter season when the water requirements are relatively low. They had a higher percentage of cropped area (9-12%) under the low value but low water requirement crops of gram and Toria, as compared to the tubewell area (0.7-3.5%). Comparison of the wheat-cotton crop rotation zones of the non-tubewell and the tubewell area shows that both the mechanized and the bullock farms in the latter area had a relatively higher percentage of the total crop acreage under cotton and a lower percentage under wheat as compared to the non-tubewell area. The supplementary water supply from the tubewells in the tubewell area has enabled all types of farms to substitute a relatively high value crop of cotton for a relatively low value[1] crop of wheat.

Table 4.13A describes the differences in cropping pattern between mechanized and bullock farms in the cotton zone. In addition to less land under fodder, tractor farms showed a significant increase under fruits and vegetables.

Similarly, in the rice zone data in Table 4.13B, fodder acreage was reduced on tractor farms. Rice acreage, however, was slightly higher on the bullock farms and wheat acreas was considerably less. These differences point towards the relative suitability of the bullock technology for rice cultivation and of the tractor technology for wheat cultivation, a point made earlier in the discussion of yield effects.

According to the data in Table 4.13C for the non-tubewell area, acreage under fodder was practically the same. The tractor farmers had reduced the number of bullocks but increased the number of milk animals. The percentage area under wheat was the same on both, but the bullock farms had a relatively higher percentage under low water using crops of gram and toria as compared to the tractor farms. In the summer season crops, the tractor

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[1]See Table 5.3.

farms had a higher percentage under cotton but less sugarcane, reflecting the labor intensity of the latter.

Extent and Pattern of Tractor Custom Work

The results of the survey indicate that the tractor services were hired for the following purposes: (1) crop cultivation, (2) wheat threshing, and (3) transportation of the farm inputs and output.

The major custom work was for crop cultivation. Table 4.14 presents the custom work by crops on the farms hiring tractor services in the cotton and the rice zone of the tubewell area. This data indicates that most of the tractor time was hired for land preparation of the two major crops sown in the winter and the summer seasons in the two cropping pattern zones. Tractor hiring was lowest for the rice crop when compared to the other major crops. This is due to the fact that the techniques of land preparation for the rice crop in this area require a major portion of the plowings to be performed while water is standing in the field. Tractors in the area do not have the necessary equipment to work in water and therefore the bullocks are used for that purpose. A second point of interest is that the percentage of plowings performed with tractor hiring was highest for the wheat in the rice zone. This results from the difficulty of breaking the hard soil crust of the rice fields in which the wheat follows.

TABLE 4.14.--The Percentage of the Plowings and the Plankings Performed by Crop, With Tractor on the Tractor Custom Farms.

Crops	Total Acreage	The Average Number of the Per Acre Plowings and Plankins		Percentage Performed by Tractor Hiring	
		Plowings	Plankings	Plowings	Plankings
		I. Cotton Zone			
Rabi 1970-71					
Wheat	181.00	8	2.8	50	. .
Fodder	24.00	3.9	1.9	. .	. .
Gram	1.50	4	1	50	. .
Toria	5.00	4.5	0.8	13.3	. .
Kharif 1971					
Cotton	106.50	4.7	2.3	41.7	. .
Fodder	28.75	5	2.8	29.4	14.3
Maize	23.50	6.9	2.6	20.3	. .
Rice	13.00	4.4	2.5	. .	. .
		II. Rice Zone			
Rabi 1970-71					
Wheat	125.00	7.4	3.7	59.5	16.2
Fodder	56.00	3.9	2	48.7	. .
Gram	7.50	6.4	2.3	65.6	. .
Kharif 1971					
Rice	138.00	8.1	4.2	22.2	. .
Fodder	54.00	9.8	4.3	44.9	. .
Cotton	2.00	8	4.2	. .	. .
Tobacco	2.00	12.5	2	40	. .

The plankings are performed mostly with bullocks, and there is very little tractor hiring for this operation.

Number and Use Pattern of Bullocks on the Tractor Farms

Most of the tractor farms have reduced but not eliminated the bullocks. According to the Report of the Farm Mechanization Committee, "Amongst the major problems faced by the tractor owners is the short supply of spare parts and unsatisfactory repairs and servicing facilities" (see 48, p. 101). Under such a situation it is quite understandable that the tractor farms would continue to keep some of their bullock power to meet any emergencies arising from a tractor breakdown. In addition, the larger farmers may find it economical to keep several pair of bullocks for additional power during the peak power periods. Data for bullocks on tractor farms, farms hiring tractor services and those using only the bullock power are given in Table 4.15. Tractor farms, as a whole, maintained a number of bullocks equivalent to a little more than one-third of the number maintained on bullock farms. The reduction in bullocks on the tractor farms was greatest in the rice area. The farms hiring tractor services maintained about one quarter less bullocks as compared to the bullock farms.

The use pattern of the bullocks on the tractor farms in different areas is given in Table 4.16. It is

TABLE 4.15.--Working Bullock Pairs on Different Types of Farms in Various Survey Areas.

	Tubewell Area						Non-Tubewell			
	Cotton Zone			Rice Zone			Lyallpur District		All Areas	
	Tractor			Tractor						
	Tractor	Hire	Bullocks	Tractor	Hire	Bullocks	Tractor	Bullocks	Tractor	Bullocks
Pairs of Bullocks per 12 1/2 acre	0.34	0.62	0.75	0.18	0.75	1.05	0.47	1.07	0.34	0.95
Index as a percent-age of Bullock farms	45	83	100	17	71	100	44	100	36	100

TABLE 4.16.--The Percentage of Plowings and Plankings Performed, by Crop, With Bullocks on the Tractor Farms in Different Areas.

Crops	Total Crop Area	The Average Number of Plowings and Plankings Per Acre of Crop		The Percentage of the Per Acre Plowings and Plankings Performed With Bullocks	
		Plowings (Number)	Plankings (Number)	Plowings (Per cent)	Plankings (Per cent)
		I. Cotton Zone			
Rabi 1970-71					
Wheat	173.00	8.1	3.3	14.8	91
Fodder	34.00	2.4	1.3	16.7	78
Gram	2.00	8	3.0	25	100
Toria	6.00	7	2.0	. .	100
Vegetables	15.00	2.5	2.0	. .	50
Kharif 1971					
Cotton	136.75	4.9	2.7	2.4	45
Fodder	39.25	6	2.0	21.3	95
Maize	12.00	9.4	5.0	6.4	60.8
Rice	5.75	7	3.5	35.7	71.4
Sugarcane	2.00	11.3	9.5	17.8	100.
		II. Rice Zone			
Rabi 1970-71					
Wheat	154.50	6.5	4.0		. .
Fodder	24.00	5	2.2		18
Toria	1.25	9.2	7.2		. .
Gram	1.75	5.8	4.9		. .
Kharif 1971					
Rice	141.50	8.9	6.0	33.7	45
Fodder	44.50	7.0	5.0	. .	. .
Cotton	1.50	5.3	5.2	. .	. .
Sugarcane	3.00	14.0	9.0	3.6	3
		III. Lyallpur Zone (Canal Water Only)			
Rabi 1970-71					
Wheat	115.75	9.2	3.3	1	79
Fodder	17.25	5.8	2.4	. .	88
Toria	13.75	6.2	2.2	6.5	96
Gram	6.50	8.4	3.5	4.8	74
Kharif 1971					
Cotton	48.75	5.4	2.5	3.0	92
Fodder	16.75	5.9	1.9	13.6	95
Maize	11.50	8.2	2.2	20.7	73
Sugarcane	19.50	9.7	5.2	29	83

evident that, by and large, the planking operation was performed by bullocks. Bullocks were also used for plowing operations on a variety of crops in different areas. It is interesting to note that, of all the major crops in different areas, the greatest use of bullocks is made for the rice crop in the rice area.

Summary

The empirical evidence on the output effects of tractor mechanization analyzed in this section are summarized below.

Effect on Cropping Intensity

The influence of mechanization on cropping intensities differed with the system of irrigation. In the Lyallpur area where, due to the saline groundwater, canal irrigation cannot be supplemented by tubewell water, tractor power did not help to increase cropping intensity. Thus, on both tractor and bullock farms intensity was almost the same (slightly more than 100 per cent).

In the sweet groundwater areas, on the other hand, where water is not a constraint, tractor cultivation led to significantly higher cropping intensity. With supplementry tubewell water even the bullock farms were able to achieve an intensity of 144 per cent. With a tractor the intensity was 168 per cent. The farms hiring tractor services attained 161 per cent intensity.

Given the flexible water supply in the tubewell areas, the influence of tractor mechanization on cropping intensity differed with the cropping pattern. In the wheat-rice area average cropping intensity on the tractor and bullock farms reached 177 and 162 per cent, respectively, but in the wheat-cotton area the corresponding figures were 162 and 129 per cent. These differences arise from the fact that while sowing and harvest seasons overlap in case of wheat-cotton, they do not for wheat-rice. Due to these seasonal overlap differences, the contribution of the tractor to cropping intensity was considerably higher in the wheat-cotton as compared to the wheat-rice area. The tractor farmers, however, do not appear to have yet exploited the potential for increasing cropping intensity by planting wheat after cotton. The new varieties of wheat and rice appear to be lessening or removing the seasonal overlapping and therefore are opening new possibilities for increased cropping intensities.

Effect on Yields

Tractors did not make any significant impact on the yields per acre. While yields differed significantly between mechanized and non-mechanized farms, there was no consistency in the direction of the difference. The reasons for the lack of any persistent effect on yields appears to be as follows:

The tractor farms did not have tractor implements for deep plowing, row crop sowing, and fertilization. The cultivator (springtooth plow) meant for seed-bed preparation was also being used for land preparation, for which it is not suitable.

The tractor has not yet been accompanied by a simultaneous increase in the bundle of inputs and improved practices. While tractor farms were using higher doses of chemical fertilizers (61 nutrients pounds per acre as compared to 51 on the bullock farms), in other practices bullock farms compared favorably. They had better sowing practices, as much or more of their wheat and rice under improved varieties, more weeding and hoeing, etc.

Effect on Cropping Pattern

The percentage area under fodder was less on the tractor as compared to the bullock farms except in the Lyallpur district where it was equal on both. The tractor farmers in Lyallpur reduced the number of bullocks but increased milk animals.

In the wheat-rice area tractor farmers had less rice and more wheat as compared to bullock farms.

In the wheat-cotton area, tractor farmers had a small percentage area under wheat and cotton but more under fruits and vegetables as compared to bullock farms.

In the Lyallpur district tractor farmers had a relatively higher area under cotton while bullock farmers had more of low value crops of gram and toria.

Tractor Custom Work

Tractor custom hiring was very widespread in the tubewell areas but almost non-existent in non-tubewell areas. It was used mostly for land preparation for the major crops of wheat, cotton, and rice. Tractor hiring which was lowest for rice and highest for wheat in the wheat-rice area, was used mostly for plowing and very little for planking purposes. Tractor farmers retained some bullocks also. On the whole, the tractor farmers had a little more than one-third of the bullocks of the bullock farms. In the wheat-cotton area they had 44-45 per cent but in the wheat-rice area only 17 per cent. Although the bullocks on the tractor farms were also used for plowings, their major use was for planking purposes. The most significant use for plowing was for rice cultivation.

Social Effects of Tractor Mechanization

This section considers the effect of the tractor mechanization on employment and the tenant-landlord relationship as it emerged from the survey data. Employment will be restricted to the on-farm employment. For analysis of the employment effects of mechanization, the main source of data will be cross-sectional data pertaining to the mechanized versus the bullock farms. While considering the effect on permanent hired labor, however, some limited use will be made of the time series data pertaining to the mechanized farms alone.

Impact of Farm Mechanization on Farm Employment

Farm labor can be divided into family labor--including the operator and the unpaid family labor--and hired labor. The latter can be further divided into permanent and casual labor.

Unemployment of different groups that constitute the labor force has varying social consequences. The "unemployment"[1] of family labor, for example, may be a voluntarily chosen leisure with no serious social repercussions. But the unemployment of hired labor will involve hardship and may lead to rural urban migration. The consequences will differ even among the hired labor depending on whether he is permanent or casual. Whereas the casual worker usually has a non-farm job in the village and uses the farm job to supplement his income, the permanent worker is wholly dependent on the farm job for his livelihood. The loss of the farm job would, therefore, mean a reduction in income for the former but total deprivation for the latter.

[1]Technically they cannot be called unemployed, though not working. They may be able but not willing to work.

The different categories of the farm labor are also interdependent.[1] One category may substitute for the other, changing the structure of the farm labor force even when there is no overall change in the use of labor. The change in the structure will have different social implications depending on whether family labor substitutes for hired labor or the other way around.

The labor group differences and the structural aspects of the farm labor force discussed above require a disaggregative analysis in terms of how mechanization influences different groups in the labor force, but later bringing them together. In the paragraphs that follow we will discuss the different categories of farm labor separately and analyze how each has been influenced by the mechanization.

Family Labor

While pre-testing the questionnaire, the author noticed that the female members of the farm families to be studied were almost wholly confined to household work, and any farm work done by them was insignificant. It was noticed further that the farmers were somewhat reluctant to answer questions about the female family members. Because of these circumstances, it was decided to exclude female labor and investigate only male family labor.

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[1]For further elaboration of the farm labor categories interdependence and substitution see (68).

The survey results show, as indicated in Table 4.17, that the number of working age[1] male members in the bullock farm household was greater than in the tractor farm household. Not all the adult members were available for work. The labor participation rate was higher in the bullock as compared to the tractor farm household (85.5 versus 75.6). (The main reason for this difference is the comparatively higher percentage of the family adults in the mechanized farm households going to school.) The division of the total family labor between farm and non-farm jobs was similar in both types of households (83 per cent working full time on farms in either case). However, family labor on tractor farms was considerably less than on bullock farms (46 versus 61).

The level of education is an important aspect of the labor force in view of its human capital and development implications. Table 4.18 shows the percentage of the labor force in both types of farm households with

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[1]The number of the working age male members was calculated as follows:

Family Male Members

Less than 10 years of age	0
10-15	1/2
16-50	1
51-60	1/2
Greater than 60	0

Any member working part-time is counted as one-half of his respective position in the above categories.

TABLE 4.17.--The Total Family Male Labor in the Tractor and the Bullock Farm Households Surveyed on the Punjab and Their Distribution Between Farm and Non-Farm Jobs, 1971.

Labor Force	Tractor Farm Households	Bullock Farm Households
Total number of Male Adults	73.7	91.7
Per cent Rate of Labor Force Participation	75.6	85.5
Total Number of the Labor Force	55.7	73.8
Labor Force Working on the Farm		
Number	46	61
Per cent of the Total Labor Force	82.6	82.6
Labor Force Working off the Farm		
Number	9.7	12.8
Per cent of the Total Labor Force	17.4	17.4

Note: Figures standardized on farm area = 800 acres each.

TABLE 4.18.--The Level of Education of the Family Labor Force in Mechanized and Bullock Farm Households Surveyed.

Place of Work	Tractor Farm Households			Bullock Farm Households		
	Total Number of Family Labor	High School and Above		Total Number of Family Labor	High School and Above	
		Number	Per cent of the Total Labor Force		Number	Per cent of the Total Labor Force
On the Farm	46.0	21.9 (69.4%)	47.5	61.0	8.8 (42.9%)	14.5
Off the Farm	9.7	9.7 (30.6%)	100.0	12.8	11.8 (57.3%)	92.3
Total	55.7	31.6 (100%)	56.7	73.8	20.6 (100%)	27.9

education through high school and above. The reason for choosing the high school level as the dividing line was that the high school degree is the minimum requirement for most of the white collar jobs in the urban areas, and the social status and the level of income of the farm households under study is such that their members normally go to the urban areas only for the white collar jobs or business. Moreover, these two levels of education differ in their importance for the employment problem. According to Ridker, the young, new labor force entrants appear to account for between 40 and 60 per cent of the urban unemployed in the Near East and South Asian Countries, and

> They are in the middle groups so far as education is concerned, typically the lowest unemployment rates are found among illiterates (and often among literates with less than a matriculate), the next lowest rates among those with college and graduate dgrees, and the highest rates among those with matriculate but less than graduate degrees (see 31, pp. 9-10).

The evidence from Pakistan itself corroborates Ridker's general observation. According to the Pakistan Fourth Five Year Plan,

> . . . certain international comparisons indicate that Pakistan belongs to a group of countries in which second (matriculates and intermediates) and third (Degree holders) level education has developed faster than education at first (Grades 5-9) level. This impression is also supported by actual developments in the 1960's. . . . The growth of both second and third levels was well above requirements as derived from economic growth during the same period. The excess of availabilities over requirements is reflected in increasing unemployment among the educated youth (see 11, pp. 108 and 113).

The data in Table 4.18 indicate that the education of the labor force in the two types of farm households differed considerably. A substantially higher per cent of the total labor force of the tractor farm households had high school and higher education, as compared to the bullock households. Thus, a greater proportion (as well as the absolute number) of labor in the mechanized, as compared to the bullock, farm households are potential entrants in the white collar urban labor market. However, the tractor farms, as compared to the bullock farms, held a major portion of their educated labor on the farm. This has served two purposes. First, it has improved the relative educational quality of the tractor farm labor, and, secondly, the migration from the farm to the non-farm labor market has been reduced. The data in Table 4.18 show that the percentage of the family labor with high school and higher education going to non-farm jobs was considerably higher for bullock as compared to tractor farms.

This survey also provides time-series data about the tractor farm family labor and its educational levels. The tractor farm operators were asked about the previous occupation of the present farm family labor before the purchase of the tractor. Table 4.19 presents the information based on their answers.

TABLE 4.19.--Previous Occupation of the Present Family Labor Force on the Tractor Farms.

Previous Occupation	Total		Education Level	
	Number	Per cent	Less than Matric	Matric and Higher
Working on the Farm	30	65.2	19	11
Working off the Farm	3	6.5	1	2
Students	13	28.2	4	9
Total	46	100	24	22

It will be noticed that before the purchase of the tractor, 6.5 per cent of the present family labor on the farm were working on the non-farm jobs and another 28.2 per cent were students. More than two-thirds of these new entrants to the farm labor market had an education level of matric and higher.

The major conclusion that emerges from the analysis of both the cross-section and the time series data on farm family labor appears to be that the presence of the tractor on the farm has led to increased participation in farm labor by the young educated members of the family who otherwise might have gone to the urban labor market in search of jobs. The answers to the unstructured questions

by the author also corroborate this conclusion.[1] Throughout the survey it was noticed that the younger generation, especially those having some level of schooling, were reluctant to accept the farm work with its traditional hardship. On the bullock farms the elderly people generally complained that the younger boys did not take an interest in the farm work.[2] This, however, was not the case on the tractor farms where the older people were mostly appreciative of the younger ones.[3] From the experience of the survey, the author feels that Abercrombie

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[1]The answer of Chaudhry Ali Muhammad of Chak. No. 311/G.B. in the Lyallpur district was typical. Ali Muhammad had two years of college education and was working on his forty-five acre farm with the tractor. When asked about the advantage of the tractor cultivation his answer was, "Without the tractor, you would not have found me on the farm. The tractor has made the farm work acceptable to me and made me stay here instead of going to the city for a job. Without the tractor the farm work day extended from two to three hours before dawn to two to three hours after dusk. With tractor we generally start our daily work after sunrise and are back home before the sun sets."

[2]While interviewing Ch Mohd Ali Sahi, a bullock farm operator of village Kotli in the Gujranmala district, the author noticed a young boy of about eighteen in clean clothes and combed hair wandering around the farm. When asked by the author who he was, Ch Sahi (the boy's father) answered indignantly, "He is our 'Sahib.' He spent eight years in school and now he wants to have good food and clothing but does not like the farm work." Ch Sahi's answer to the question of why the boy does not like the farm work was, "It is not his fault. The younger generation in general does not want to work on the farms, the way we have been doing."

[3]The three elder brothers of Ch Ali Muhammad, the tractor farm operator in the Lyallpur district, sat proudly and appreciatively around him while he answered the author's questions.

pinpoints an important complexity underlying the whole issue of mechanization and employment when he says,

> The lightening of agricultural toil is one of the most important effects of mechanization in the context of the employment problem. A major dilemma in determining a mechanization policy to meet employment needs is that, while tractors contribute to driving people out of agriculture, it is nevertheless difficult to see how the younger generation can be persuaded to stay in agriculture without some lightening of the work involved (see 4, p. 20).

Next we will consider whether and how far the tractors on the farms surveyed in the Punjab have "contributed to driving people out of agriculture."

Permanent Hired Labor

The permanent farm labor in the Punjab is generally hired for a period of one year, though in some areas the practice of monthly contracts also exists. They are usually supposed to be present on the farm around the clock for twenty-four hours. Besides taking care of the draught and milk animals on the farm, their major assignment on the farm is land cultivation. Thus when the tractor replaces the bullock plow for the cultivation of land, the permanently hired labor is the most immediate group to feel the pinch.

The influence of the tractor mechanization on permanent labor on the surveyed farms will be analyzed (1) through a cross sectional comparison with the bullock farms, and (2) by studying the "before" and "after" labor situation on the tractor farms. Since the demand for the permanent hired labor is likely to be influenced by the supply of the family labor, the family farm labor picture will also be presented, to serve as a background against which to have a better appreciation of the influence of mechanization on the permanent hired labor. Table 4.20 gives a comparative picture of the permanent hired labor along with the family labor on the tractor and bullock farms surveyed.

The data shows that there was not much difference in the number of the permanent labor hired on the two types of farms. The tractor farms hired only 3.7 per cent less labor as compared to the bullock farms. But the bullock farms had a considerably larger supply of family labor which tended to depress their demand for hired labor. Considering both the family and the hired labor, the tractor farms were using about 17 per cent less labor as compared to the bullock farms.

Time series data on how the permanent labor employment on the tractor farms changed with the purchase of the tractor is shown in Table 4.21. The number of permanent hired and family labor on these farms are shown before and after acquisition of the tractor. After the tractor permanent hired labor decreased by 19 per cent. But at the same time family labor increased by about 32 per cent. In absolute numbers the tractor drove about

TABLE 4.20.--Total Family and Permanent Hired Male Labor Working on the Tractor and Bullock Farms Surveyed.

	Tractor Farms				Bullock Farms			
	Total Area Under Own Cultivation 1970-71 (Acres)	Family Labor (Number)	Permanent Hired Male Labor (Number)	Total	Total Area Under Own Cultivation 1970-71 (Acres)	Family Labor (Number)	Permanent Hired Male Labor (Number)	Total
Cotton Area	317	14	17	31	304.5	17.75	15	32.75
Rice Area	205	9	7.5	16.5	238	12.50	17	29.50
Lyallpur Area	266.50	22.25	14.50	36.75	273	33	10	43
All Areas	786.50	45.25	39	84.25	815.5	62.25	42	105.25
Per	800	46	39.67	85.67	800	61	41.20	103.20

TABLE 4.21.--The Number of Permanent Hired Labor and Family Labor Before and After the Tractor on the Mechanized Farms Surveyed.

Survey Area	Permanent Hired Labor (Number)					Family Farm Labor (Number)				
	Before the Tractor		After the Tractor[a]		Per cent	Before the Tractor		After the Tractor[a]		Per cent
	Labor (Number)	Farm Area (Acres)	Labor (Number)	Farm Area (Acres)	Change Increase (+) Decrease (-)	Labor (Number)	Farm Area (Acres)	Labor (Number)	Farm Area (Acres)	Change Increase (+) Decrease (-)
1. Cotton Area	20	292.5	17	317.0		15.8	292.5	22.3	317.0	
2. Rice Area	11	192.5	7.5	205.0		6.0	192.5	9.0	205.0	
3. Lyallpur Area	11	199.5	14.5	264.5		8.0	199.5	14.0	264.5	
4. Total (1+2+3)	42	684.5	39.0	786.5		29.8	684.5	45.3	786.5	
Total per 800 Acre Farm Area	49	800	39.7	800	-19	34.8	800	46	800	+32.3

[a]After the tractor labor force and farm area refers to the crop year 1970-71.

nine permanent hired laborers off the farms but brought in about eleven family members to work on the farms.[1]

From this analysis of the data, it is concluded that on the mechanized farms surveyed the introduction of the tractor has not reduced the overall permanent labor. The structure of the labor force, however, has changed. The tractor led to an increase in the supply of the family labor, which has reduced the demand for hired permanent labor.

Casual Labor

We turn now to a cross-sectional comparison of the amount of casual labor used on the mechanized and the bullock farms surveyed in the Punjab. The amount of total labor used will be derived from the cropping intensities, the cropping patterns, the yields, and the casual labor used per acre of different crops on the two types of farms

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[1]The nineteen tractor farm operators had the following number of years to make the adjustment.

Number of Tractor Farm Operators	Number of Years Available for Making Adjustments
5	1
2	2
4	3
4	4
2	5
2	9
Average	3.4

under study. The labor used per acre of different crops is presented and explained in Appendix A. It will be seen that not all crops necessitate casual labor, and those using it differ in intensity of the labor used.

The use of casual labor on the tractor and bullock farms in the different survey areas is shown in Table 4.22.

TABLE 4.22.--Casual Labor Used Per Cultivated Acre on the Tractor and the Bullock Farms Surveyed.

	Tractor Farms	Bullock Farms	Percentage Difference Between 1 and 2 (1-2)
	(Manhours of the Casual Labor Used Per Cultivated Acre)		
Cotton Zone	167	121	+38
Rice Zone	110	103	+ 6.8
Lyallpur Zone	91	95	- 4.2
Total	127	107	+18.7

On the whole, tractor farms used 18.7 per cent more casual labor per cultivated acre as compared to the bullock farms. There were, however, substantial zonal differences. The amount of labor used was comparatively greatest on both types of farms in the cotton zone of the sweet-water area. Moreover, the difference in the labor use between the tractor and the bullock farms was also greatest in this area. The detail given in Table 4.23 shows that wheat

TABLE 4.23.--A Total Use of Casual Labor on Tractor and Bullock Farms in the Punjab--1970-71.

Crops	Tractor Farms	Bullock Farms	Tractor-Bullocks
	(Man Hours)		
	I. Cotton Area		
Wheat	12,456	10,116	+2,340
Toria	192	56	+136
Gram	44	28	+16
Tobacco	1,440	366	+1,074
Cotton	19,282	21,648	-2,366
Maize	1,050	364	+686
Rice	299	520	-231
Sugarcane	3,725	2,932	+793
Vegetables	14,484	778	+13,706
All Crops	52,972	36,808	+16,164
Per Cultivated Acre	167	121	+46
	II. Rice Area		
Wheat	11,124	7,906	+328
Toria	40	176	-136
Gram	20	48	-28
Cotton	138	207	-69
Rice	10,613	14,896	-4,283
Sugarcane	689	1,272	-583
All Crops	22,624	24,505	-1,881
Per Cultivated Acre	110	103	+7
	III. Lyallpur Area (Canal Water Only)		
Wheat	8,334	8,676	-342
Toria	568	744	-176
Gram	106	152	-46
Cotton	6,727	4,397	+2,330
Maize	575	702	-127
Sugarcane	7,113	9,716	-2,603
Vegetables	728	1,719	-991
All Crops	24,151	26,106	-1,955
Per Cultivated Acre	91	95	-4

and cotton, the two main crops, balanced out in their use of the casual labor force on the two types of farms. The relatively greater area under the minor but mostly labor intensive crops like tobacco, maize, sugarcane, and vegetables on the tractor farms accounted for the relatively higher use of casual labor.

In the rice zone both types of farms had considerably higher cropping intensity (see Table 4.1) but lower use of the casual labor per cultivated acre compared to the cotton area. This is due to difference in the labor intensity of the crops grown in the two zones. Wheat is common to both areas, but the second major crop, cotton, is much more labor intensive than rice. Moreover, the minor but highly labor intensive crops grown in the cotton area are relatively unimportant in the rice area. The casual labor used per cultivated acre on the tractor farms was only 6.8 per cent higher as compared to that of the bullock farms in the rice area. The small difference in the labor use is explained by the correspondingly small difference in the level of their cropping intensities, no appreciable difference in their cropping patterns in terms of the labor intensity of the crops grown, and the higher yield per acre of rice on the bullock farms which counterbalances the labor effect of higher wheat yield on the tractor farms. There were small differences in the Lyallpur zone of the saline-water area, with the tractor farms using less casual labor than the bullock farms. The relatively higher labor use on the bullock farms appears to be due mainly to their higher cropping intensity and relatively more area under the labor intensive crops of sugarcane and vegetables.

Total Labor

The family labor and the hired labor, both permanent and casual, are brought together in this section to present the overall employment impact of mechanization. Table 4.24 gives the consolidated employment picture. The data in the table is based on the assumption that the family and permanent hired labor are fully employed for 8 hours a day, 24 days a month, throughout the year. This assumption is more likely to hold in the case of hired labor (which has to be paid) than the family labor. To the extent underemployment prevails among the family members, the employment results will be biased in favor of bullock farms which have relatively greater family labor as compared to the tractor farms.

Table 4.24 indicates that on the whole tractor farms had 7 per cent less labor per cultivated acre as compared to the bullock farm. The composition of the total, however, shows that the use of hired labor (both permanent and casual) on the tractor farms was 7 per cent higher but they had 24 per cent less family labor as compared to

TABLE 4.24.--Total Labor Used Per Cultivated Acre on the Tractor and Bullock Farms Surveyed in the Punjab, 1970-71.

Survey Area	Tractor Farms			Bullock Farms			Percentage Difference Between Tractor Bullock Farms (T-B)		
	Family Labor	Hired* Labor	Total Labor	Family Labor	Hired* Labor	Total Labor	Family Labor	Hired* Labor	Total Labor
	(Manhours per cultivated acre)								
Cotton Area	102	291	393	134	234	368	-24	+24	+7
Rice Area	101	194	295	121	267	388	-17	-27	-24
Lyallpur Area	192	216	408	278	179	457	-31	+21	-11
All Areas	133	241	374	176	226	402	-24	+7	-7

*Includes both permanent and casual hired labor.

Note: Family and permanent hired labor are assumed to work for 8 hours a day for 24 days a month.

the bullock farms. It will be noticed from the table that results varied between different areas. While both hired and total labor use on the tractor compared to the bullock farms was greater in the cotton area, it was lesser in the rice area. In the Lyallpur area, use of hired labor was greater but total labor was lesser on the tractor farms.

Influence of Farm Mechanization on Tenurial Relationships and the Size of the Farm

The impact of mechanization on landlord-tenant relationships can be examined in two stages. The first is identified with the use of the machine power for lifting groundwater. Both types of farms, i.e., the ones which later purchased a tractor and those which did not and continued with bullock cultivation, will be discussed. The second step involves the introduction of tractors for crop cultivation purposes. In both cases, the analysis will focus on the impact of the new technology on the tenant class.

Influence of the Tubewell

Table 4.25 shows the number of tenants and the land area cultivated by them after the owner-operators surveyed in the Punjab installed the tubewells. The data shows that in total 71 per cent of the tenants were ejected after the tubewells were installed by the land

TABLE 4.25.--The Effect of the Tubewell on the Operational Holding of the Tubewell Owners and on Their Tenants.

	Total Area Under Cultivation in the Village of Residence	Own Cultivation		Tenant Cultivation			
		Area		Area Under Cultivation		Tenants	
		Percentage of the Total	Average Holding Size	Percentage of the Total	Average Holding Size	Number	Percentage Displaced
		I. The Cotton Area					
Before the Tubewell	670.5	72	34.5	28	13.4	14	
After the Tubewell	677.5[a]	83	40.3	17	14.2	8	43
		II. The Rice Area					
Before the Tubewell	429	63	26.9	37	9.4	17	
After the Tubewell	455.5[b]	95	43.0	5	25.0	1	94
		III. Both Cotton and Rice Areas					
Before the Tubewell	1,099.5	68	31.3	32	11.2	31	
After the Tubewell	1,133.0	88	41.4	12	15.4	9	71

[a]The increase in the area all due to land renting.

[b]The increase in the area due 3.5 acre of land purchase and 23 acres of land renting.

owner. The percentage of tenants ejected was higher in the rice area than the cotton area, although the average size of the land holding under the remaining tenants increased in both areas.

Tubewell farm owners increased the area under their own cultivation after they installed the tubewell. As indicated in Table 4.25 there were three sources of the pressures that contributed to an increase of their own cultivation land holding. Tenant displacement, as already discussed, was the major source of the additional land. The second major source was land renting by the tubewell farm operators. The third source was land purchase.

Influence of the Tractor

The effect of the tractor on tenant displacement and the size of the operational holding of the tractor owners are indicated in Table 4.26.

Table 4.26 suggests that the influence of tractor mechanization on the tenurial relationship and the size of the farm cultivated by the tractor owners and their tenants has been very similar to that of the tubewell. In all areas taken together, 82 per cent of the tenants were displaced, reducing their number from 17 to only 3. Eviction was greatest in the saline groundwater area where the tractors were not preceded by tubewells. In the cotton and the rice areas, tubewells displaced most of the tenants (6 out of 14 in the cotton and 16 out of 17

TABLE 4.26.--The Influence of the Tractor on the Operational Holding of the Tractor Owners and on Their Tenants.

	Total Area Under Cultivation in the Village of Residence (Acres)	Own Cultivation: Area		Tenant Cultivation: Area Under Cultivation		Tenant Cultivation: Tenants	
		Percentage of the Total	Average Holding Size (Acres)	Percentage of the Total	Average Holding Size (Acres)	Number	Percentage Displaced
I. The Cotton Area							
Before the Tractor	340	86	41.8	14	11.9	4	
Winter 1971-72	415[a]	92	54.6	8	16.2	2	50
II. The Rice Area							
Before the Tractor	217.5	89	38.5	11	25	1	
Winter 1971-72	230.0[b]	100	46.0	. .	. .	. .	100
III. The Lyallpur Area							
Before the Tractor	343.0	58	28.5	42	12.0	12	
Winter 1971-72	390.5[a]	98	54.8	2	7	1	92
IV. All Areas							
Before the Tractor	900.5	76	36.0	24	12.7	17	
Winter 1971-72	1,035.5	96	52.4	4	13.2	3	82

[a]Increase in the area all due to land purchase.

[b]Increase in the area all due to land renting.

in the rice area) and did not leave much to be displaced by the tractors.

By reducing the land cultivated by tenants, the tractor owners increased the size of their operational holdings. Like the tubewells, the tractors also led to "indirect" tenant ejection when the tractor owners increased their cultivated area through land renting. The third source of increase in the area under the cultivation of the tractor owners was the purchase of the land.

While emphasizing the favorable output and the employment effects of the tubewell mechanization, previous studies (9, 24, 44) have ignored its impact on the tenant displacement. The present survey suggests that, insofar as the displacement of tenants is concerned, the impact of tubewells has been comparable to that of tractor mechanization.

The theoretical explanations of the tenant displacement by the owner operator acquiring a tractor are well known. Since tractors require large input, it pays for him to increase the area under own cultivation in order to reduce per acre costs. Economic theory also provides explanation of why an operator installing his tubewell may displace his tenant to increase his operational holding. Assuming that the landlord and his tenant were in equilibrium with respect to their tenurial arrangement, the tubewell, by raising the agricultural productivity of other factors, injects an element of disequilibrium into their relationship. The equilibrium might be restored by changing the rental share. But if the rental shares are not flexible enough, as they generally are not, then taking over the land for self-cultivation is one of the predictable courses of action that the tubewell owner might take.[1]

During the course of the survey the author noticed that in an environment of rising agricultural productivity, any arrangement that increases the land handling capability of the owner operator could lead to tenant displacement. For example, in a number of cases land consolidation enabled the tubewell farmers to reduce fragmentation and increase the ability of the larger cultivators to bring their entire holdings under self-cultivation. The result was to further increase the rate of tenant evictions. It was also noticed that because of their mobility, tractors can be used to farm several pieces of land as a unit that had heretofore been farmed separately. As Chaudry Ali Mohammed, a sample farmer, said,

> In addition to my 45 acre farm in this village, I own an area of 45 acres in the village of Noorpur at a distance of 1 1/2 miles from here. With the tractor I can handle that land myself and am therefore going to take over self-cultivation next year.

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[1]For an elaborated explanation of the theory and its empirical verification in Taiwan see, Steven N. S. Cheung, The Theory of Share Tenancy (Chicago: The University of Chicago Press, 1972).

It appears that it is not specifically the tractor but any technological change that raises the productivity of land that generates economic incentives for the landowners to eject the tenants and reclaim land for self-cultivation. As shown above, in the sweet groundwater areas most of the tenants were displaced before the tractor when tubewells were installed by the landowners. In the saline groundwater area, however, where tubewells were not possible, tenant displacement has been greatest after the tractor. As will be shown later (Chapter V), the net benefits from tractor mechanization in this area are negative. It is, therefore, not the tractor but, presumably, the use of high yielding seed varieties which have provided the economic incentive to resume land for self-cultivation. It was shown earlier that most of the tractors were purchased after the new wheat varieties had been introduced in this area, i.e., within the five years before the survey in 1970-71. The role of the tractor in this area has been as an "enabling" factor to capture the benefits of higher productivity on the tubewell farms; however, as will be shown in Chapter V, tractor cultivation itself is highly profitable and therefore provides an incentive to reclaim land for self-cultivation.

Summary

A summary of the influence of mechanization on employment of labor and on tenant-landlord relationships follows:

Labor Employment

The number of working age males was greater in the bullock than in the tractor farm households. Moreover, the rate of participation in the labor force was higher in the bullock farm households mainly because a relatively smaller percentage of their members go to school. As a result, bullock farms has 61 family workers as opposed to 46 on a comparable area under tractor farms. The smaller family labor may be one reason why tractor farms decided to mechanize.

About 48 per cent of the family labor on tractor farms have education through high school and above as compared to about 15 per cent on the bullock farms. Of the total family members having education through high school and above, 31 per cent in the tractor and 57 per cent in the bullock farm households left for off-farm jobs. It appears that the tractor cultivation has increased participation in the farm labor force by the young educated members of the family who are the potential entrants to the white-collar urban labor market. The income level and social status of the farm households studied is such that migration to the urban jobs is limited mainly to the educated members while the uneducated stay on the farm in preference to the blue-collar jobs in cities.

Tractor farms used slightly less (3.7%) permanent labor as compared to bullock farms. On the tractor farms themselves, however, permanent labor decreased by 19 per cent after the tractor. The use of casual labor was about 19 per cent greater on the tractor compared to the bullock farms.

On the whole, tractor farms were using 7 per cent less labor per cultivated acre as compared to the tractor farms. However, they had 7 per cent more hired labor but 24 per cent less family labor.

Tenant-Landlord Relationships

The influence of tubewell and tractor mechanization on tenurial relationships and the structure of the farm was very similar. In both cases there was widespread displacement of tenants and an increase in the size of the farm under own cultivation of the mechanized farms. The major source of increase in the farm size was tenant displacement. Land renting and purchase were the other sources.

CHAPTER V

A PROGRAMMING APPROACH TO THE ECONOMICS OF TRACTOR MECHANIZATION IN THE PAKISTAN PUNJAB

In the preceding chapter, the present influence of tractor mechanization on output and employment was analyzed on the basis of the farm level field survey data. In this chapter a linear programming model will be described and used to predict the output and employment consequences on the assumption that farmers seek to maximize net revenues. Moreover, the rate of return on tractor mechanization will be calculated as well as the influence of several changes in the mechanization package upon this rate of return.

The Linear Programming Model

Structural Specification of the Model

Mathematical and Schematic Representation

The objective of the model is to maximize

$$(1) \quad R = \sum_{i=1}^{\ell} c_i x_i - \sum_{i=\ell+1}^{m} d_i x_i - \sum_{i=m+1}^{n} e_i x_i$$

where

c_i = the per acre net revenue obtained from the i-th crop activity

d_i = the per hour variable cost of the i-th tubewell water pumping activity

e_i = the per hour wage paid for the i-th labor hiring activity

The objective (1) is to be maximized subject to the following constraints:

$$(2)\quad \sum_{i=1}^{n} a_{ij}x_i \leq b_j \;,\quad j=1, \text{--------------}P$$

$$(3)\quad \sum_{i=n+1}^{w} a_{ij}x_i \geq b_j \;,\quad j=P+1, \text{--------------}Z$$

where

a_{ij} = the input-output coefficient of the j-th resource for one unit of the i-th activity

b_j = a vector of resource availability

The schematic representation of the model is given in Table 5.1.

Description of the Model

The Objective Function.--The objective of the model is to maximize the net revenue of the farm subject to the technical constraints of the production function and the level of available resources. Three types of variables influence the net farm income. The first is the net revenue (gross revenue-variable costs) per acre of the different

TABLE 5.1.--Schematic Representation of the Linear Programming Model.

Resource Availability	Objective Function Resource Constraints (Number)	Rs (Net)/Acre Field Crops (32)	Rs/Acre Inch Tubewell Water Pumping (14)	Rs/Hour Labor Hiring (14)
Land (Acres)	14	Land Requirement (1)	-	-
Canal Water (Acre/Inches)	14	Water Requirement (Acre/Inches)	Additional Pumped Water (-1)	-
Bullock Power (Hours)	14	Bullock Power Requirement (Hours/Acre)	-	-
Family Labor (Hours)	14	Labor Requirement (Hours/Acre)	-	Additional Labor Hired (-1)
Tractor Capacity (Hours)	14	Tractor Power Requirement (Hours/Acre)	-	-
Tubewell Capacity (Hours)	14	-	Tubewell Capacity Used (1)	-
Maximum Fodder for Bullocks (Maunds)	2	Fodder Per Acre (Maunds)	-	-
Minimum Fodder for Bullocks (Maunds)	2	Fodder Per Acre (Maunds)	-	-
Maximum Sugar Acreage	1	Land Requirement in Sugar Cane (1)		-

field crops. The net revenue is entered with a positive sign for all crops except for the minimum fodder for the bullocks, which is shown with a negative sign. In this case, net revenue shown is equal to the variable cost per acre. The variable cost of bullock fodder, an intermediate product, is taken as a reward for the draught power supplied by them. Two other variables (activities) influencing net revenue are the variable cost of pumping an acre inch of tubewell water and the hourly wage for hiring the labor. Both of these are shown in the objective function with negative signs. The wage rates included are higher for the peak labor demand months of April to June and October to November.

<u>The Activities</u>.--The model has two types of activities: the field crop and the resource-augmenting activities. The selection of field crop activities is based on the results of the field survey. They are representative of the crops grown in those irrigated areas of Punjab where wheat and cotton are the major winter and summer crops. In the survey, these areas are represented by the Sahiwal District in the sweet groundwater area and the Lyallpur District in the saline groundwater area.

The model contains two types of crop rotations for wheat: wheat after fallow and wheat following the previous season's crops. The survey results indicated that bringing in wheat after the previous season's crops is the main mechanism available for raising cropping intensities in irrigated areas.

Crop activities have also been differentiated on the basis of technology. Thus, the same crop may enter the model as more than one activity depending on different technologies being applied in its cultivation. The survey identified two types of technological differences: the seed variety and the source of power input. Significant varietal improvements have taken place in wheat, rice, and maize (corn). The farmers have shifted, almost completely, from the traditional to the improved variety of wheat but both were being followed in the case of rice and maize. Thus, on the basis of variety, wheat appears in the model as a single activity whereas rice and maize are included as two activities. Each crop is further broken up into two activities corresponding to the bullock and the mechanical technology.

The crop activities selected are:

Rabi (Winter) Season Crops

Bullock Technology	Tractor Technology
Wheat - improved	Wheat - improved
Berseem (Fodder for sale)	Berseem (Fodder for sale)
Berseem (Fodder for own bullocks)	-
Toria	Toria
Gram	Gram

Kharif (Summer) Season Crops

Bullock Technology	
Jowar (Fodder for sale)	Jowar (Fodder for sale)
Jowar (Fodder for own bullocks)	-
Rice - IRRI - improved	Rice - IRRI - improved
Rice - Basmati - traditional	Rice - Basmati - traditional
Maize - traditional	Maize - traditional
Maize - improved	Maize - improved
Mung	Mung
Sugarcane	Sugarcane

Two-Crop Joint Activities

Crops Following Previous Season's Crops

Bullock Technology	Tractor Technology
Cotton - wheat	Cotton - wheat
Maize - wheat	Maize - wheat
Rice - wheat	Rice - wheat

In the joint crop activities, wheat, maize, and rice are all of improved seed variety.

In addition to the crop activities, the model has two types of resource-augmenting activities, namely tubewell water pumping and labor hiring activities. These activities permit the farmer to augment the available canal water and the family labor through pumping tubewell water and hiring labor, respectively.

The Constraints.--Besides some special constraints, the representative model farm operator has fixed amounts of land, water, bullock power, family labor, tractor, and tubewell capacity. The amounts of these resources available over a year have been divided into monthly constraints except for October and November when it is bi-monthly.

The monthly and bi-monthly split on the supply side of the resources is necessitated by the nature of the farm demand for them. Due to the highly seasonal nature and rigidity of the field crop's demand for resources, the quantity available in each season becomes extremely important. The months of October and November have been split because with the harvest of summer and sowing of winter crops occurring in this period, the fortnightly break becomes important for making the land freed by the summer crops available for the winter crops. The monthly and bi-monthly split of resources improves the ability of the model to capture the timeliness of harvest and sowing operations. This achievement, however, is at the cost of resource supply rigidity because the inter-month and inter-fortnightly transfer of resources is not possible.

Land Constraint.--The overall land area available for raising the field crops is limited by the size of the farm. The size of the representative model farm is taken at 50 acres, which closely corresponds to the average size of the farm emerging from the field survey (Tables 4.4 and 4.5). For reasons given above, the overall land constraint is expressed as 14 monthly and bi-monthly constraints.

Water Constraints.--In the absence of a tubewell, water availability is limited by the amount of canal water allocated by the government for the farm. The canal water supply varies in proportion to the size of the farm. C. H. Gotsch has made a micro watercourse study in the Punjab and developed data on the monthly acre inches of canal water available at field level for a farm of 12.5 acres in the cotton area (see 70, Table 6.1). By proportionately varying this data we have obtained the monthly canal water available for a 50-acre farm. Again, for the peak months of October and November, the water availability is presented on a fortnightly basis.

Bullock Power Constraint.--The survey results indicated that on the average, the farmers maintained four pairs of bullocks on a 50-acre farm. These results are corroborated by another study made recently by Naseem (see 45, page 141). For each pair of bullocks, the bullock hours available depend on the number of hours per day and the number of days per month worked by the bullocks. It has been assumed that the bullocks can work eight hours a day[1] for twenty-four days a month, i.e., 192 hours a month or 96 hours a fortnight.

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[1]Naseem (45) and Inderjit, et al. (69) have also used eight hours per day. They, however, assume 269 and 250 days per year, respectively, against 274 assumed in this study.

Family Labor.--The availability of family labor has been determined on the basis of the survey results. The average number of male adults equivalent available for the farm work on a 50-acre farm was found to be as follows:

	Tractor Farm	Bullock Farm
Cotton zone of the sweet water area	2.5	3.5
Cotton zone of both the sweet and the saline water areas	3	4.3

For comparative purposes, the family labor force has been assumed as 3 for both the tractor and the bullock farms. The work capacity has been assumed at eight hours a day and twenty-four hours a month, which gives 576 man hours of family labor per month.[1] Like other fixed resources, the family labor constraint also has been expressed in monthly and bi-monthly constraints.

Tractor Capacity.--Theoretically, it is possible to run the tractor twenty-four hours a day. It is not possible in practice, however, when the tractor is supposed to work day after day over its lifetime. For short periods of time and in order to handle the seasonal peak work load, the tractor may work for relatively longer hours, but that will not be true for the year-round work. For the model

[1]The working hours per day and the days per year used here are very close to those used by Naseem (45). He uses eight hours a day and 282 days a year.

it has been assumed that the tractor can work for ten hours a day and thirty days a month,[1] i.e., 300 hours a month or 150 hours a fortnight.

Tubewell Capacity.--On the basis of observations made during the survey, it has been assumed that a tubewell can run sixteen hours a day for thirty days a month. This gives 480 tubewell working hours. With the average capacity of the private tubewells in the Punjab at 1 cusec, their water pumping capacity is therefore around one acre inch of water per hour. It is assumed that an acre inch available per hour is net of irrigation losses in distribution channels. Thus, 480 acre inches of tubewell water can be pumped per month and made available at the field head for the field crops on the farm.

Special Constraints.--The model contains special constraints which restrict the feasible cropping pattern to one that includes a minimum of fodder for the bullocks on the bullock farms and not more than a certain minimum of sugarcane and fodder for commercial sale. Following Bose and Clark (6), the bullock fodder requirements have been taken at one acre per pair in each of the winter and summer seasons. The maximum acreage constraint on sugarcane and fodder arises from market limitations. The

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[1]Inderjit (69) also uses ten hours a day and thirty days a month.

distinctive feature of these crops is that they are very profitable at the micro level but have a limited and relatively inelastic total demand. If left unconstrained, they lead to a cropping pattern which cannot be sustained at the aggregate level. The maximum constraint on sugarcane is placed at three acres, which is equivalent to the level observed during the field survey on a 50-acre farm. In the case of fodder for sale, the maximum acreage has been somewhat arbitrarily fixed at four acres in each season.

Table 5.2 gives a consolidated picture of the fixed resources available to a 50-acre farm as discussed above.

Model Data and Their Sources

To determine the parameters of the model, data were required on the fixed resources available to the farm, the inputs of different fixed resources required to produce a unit of various field crops, and the net revenue from a unit of output of these crops. The fixed resource availability was discussed in the previous section; the latter two data categories will be considered in this section.

To determine the input-output relationships, the output unit is taken as the produce per acre of a crop. Thus, the input-output relationships involve the determination of the inputs required per acre to produce a given output. The calculation of net revenue involves data on the crop yields per acre, the harvest prices, and the

TABLE 5.2.--The Fixed Resources Available to a 50-Acre Farm in the Cotton Area of the Punjab, 1971.

Months	Fixed Resources					
	Land (Acres)	Canal Water (Acre Inches)	Bullock Power (Pair Hours)	Family Labor (Man Hours)	Tractor Capacity (Hours)	Tubewell Capacity (Hours)
January	50	122	768	576	300	480
February	50	148	768	576	300	480
March	50	164	768	576	300	480
April	50	134	768	576	300	480
May	50	160	768	576	300	480
June	50	148	768	576	300	480
July	50	146	768	576	300	480
August	50	144	768	576	300	480
September	50	156	768	576	300	480
October-1st half	50	54	384	288	150	240
October-2nd half	50	54	384	288	150	240
November-1st half	50	34	384	288	150	240
November-2nd half	50	34	384	288	150	240
December	50	59	768	576	300	480

variable cost per acre. The variable costs include the cost of seed, fertilizer, pesticides, water, land revenue, and marketing charges.

The data were obtained from three main sources: published and unpublished documents; interviews with the officials and experts in government departments; research institutes and private agencies; and the field survey and unstructured questions asked of the farmers and the local agriculture extension workers. A new source did not always mean new information. Often they supplied information used for checking the earlier data. The checking and cross-checking facilitated our judgment in the final selection of data for inclusion in the model.

Input-Ourput Relationship

Initially, data were obtained from the World Bank study on the development of irrigation and agriculture in West Pakistan (30); "The Field Crop Technology in the Punjab, India" by Singh et al. (68); Ph.D. theses by Naseem (45) and Gotsch (27) and an unpublished report by Eisel on "A Mixed-Integer Programming Model for Punjab Agriculture" (17). The theses by Naseem and Gotsch, which developed programming models for small farmers in the Punjab, along with the Eisel report, provided a number of crude parameter estimates that were subsequently refined and supplemented by additional field work in the Pakistan Punjab.

The final input-output relationships were developed in Pakistan, mostly through discussions with the experts at the Punjab Agricultural Research Institute in Lyallpur. With the help of the Director, a team of experts consisting of the agronomist and two farm managers was organized, and about a week was spent in discussion with them. By this time, the field survey and the preliminary coding of the data had been completed. During discussions the survey data and the crude data collected earlier from the published and unpublished documents were used for checking and cross-checking purposes. In addition to the fixed inputs, the variable inputs of seed, fertilizer, and pesticides were also considered in order to ensure that the output assumed correspond to the full package of inputs, both fixed and variable. The discussion in the agronomy section had to be supplemented by specific interviews with experts in some other special areas, e.g., the engineering workshop and crop experiment stations, to fill in the remaining gaps in the data.

Net Revenue

The calculation of the net revenue uses data on the crop yields per acre, the harvest prices, and the variable costs. The yields per acre are taken from the input-output relationship calculations. The data on the harvest prices were available from the Directorate of Agricultural Economics and Marketing, Lahore. The variable costs include seed, fertilizer, pesticides, water rate, land tax, and marketing charges. The data on seed, fertilizer, and pesticide prices were available from the departments of Planning and Development and Agriculture, while their quantities were determined during the discussion on the input-output functions. The water rate and the land tax data were obtained from the Irrigation and Revenue Departments, respectively. The marketing and municipal committees had data on marketing charges. Table 5.3 gives the yields, prices, variable cost, and net revenue per acre of crop activity used in the model. The details of the variable costs by items are presented in Table 5.4.

Initial Results of the Programming Exercise: The Basic Solution

This section presents the basic solution of the programming model. The analysis centers on the effect of mechanization on cropping intensity, cropping pattern, and net farm revenue. The discussion will serve two purposes: (1) to check the "survey" with the "model" results and thereby provide evidence on the soundness of the former and realism of the latter and (2) to highlight the mechanisms through which the model generates benefits and thus to lay the groundwork for the study of the rate of return on mechanization in the following section.

The model is only for part of the survey areas, namely those irrigated areas of the Punjab where wheat and cotton are the major winter and summer crops. The data for

TABLE 5.3.--Gross Revenue, Variable Costs, and Net Revenue per Acre of Crop Activities Used in the Programming Model.

Crop Activity	Power Technology	Yield Per Acre		Price Per Maund	Gross Revenue Per Acre	Variable Cost Per Acre	Net Revenue Per Acre
		Grain/ Leafage (Maunds)	Straw (Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)
Wheat	Tractor	40	40	17	720	190.4	530
	Bullocks	40	40	17	720	148.4	572
Gram	Tractor	12	6	25	306	103.4	203
	Bullocks	12	6	25	306	57.4	249
Toria	Tractor	10	5	24	245	119.2	126
	Bullocks	10	5	24	245	72.2	173
Rabi Fodder (Sale)	Tractor	700	-	1	700	192.0	282
	Bullocks	700	-	1	700	418.0	508
Rabi Fodder (Bullocks)	Bullocks	-	-	-	-	67.6	67.6
Rice - IRRI	Tractor	40	40	12	520	185.8	334
	Bullocks	40	40	12	520	148.8	371
Rice - Basmati	Tractor	20	20	17	360	166.8	193
	Bullocks	20	20	17	360	119.7	240
Maize-Desi	Tractor	20	40	15	340	145.0	195
	Bullocks	20	40	15	340	98.0	242

Maize-Hybrid	Tractor	30	40	15	490	184.0	306
	Bullocks	30	40	15	490	142.0	348
Kharif Fodder (Sale)	Tractor	450	-	0.88	396	126.0	270
	Bullocks	450	-	0.88	396	296.0	100
Mung	Tractor	8	-	30	240	91.3	149
	Bullocks	8	-	30	240	45.3	195
Kharif Fodder (Bullocks)	Bullocks	-	-	-	-	71.0	71
Cotton	Tractor	15	12	50	762	186.0	576
	Bullocks	15	12	50	762	149.6	612
Sugarcane (Gur)	Tractor	60	20	40	2420	677.0	1743
	Bullocks	60	20	40	2420	591.0	1829
Cotton/Wheat	Tractor	14.7/36.7	12/36.7	50/17	1408	376.8	1031
	Bullocks	14.7/36.7	12/36.7	50/17	1408	300.5	1108
Rice/Wheat	Tractor	40/36.7	40/36.7	12/17	1181	382.0	799
	Bullocks	40/36.7	40/36.7	12/17	1181	293.0	888
Maize/Wheat	Tractor	30/36.7	40/36.7	15/17	1151	372.0	779
	Bullocks	30/36.7	40/36.7	15/17	1151	289.0	862

TABLE 5.4.--Variable Costs Per Acre of Crop Activities Used in the Programming Model.

Crop Activity	Power Technology	Variable Costs Per Acre in Rupees							
		Seed	Fertilizer	Pesticides	Fuel, Repairs and Spares	Canal Water	Land Revenue	Marketing Charges	Total
Wheat	Tractor	22.0	66.5	-	62	10.4	12.15	18.4	190.4
	Bullocks	22.0	66.5	-	-	10.4	12.15	38.4	148.4
Gram	Tractor	15.0	9.5	-	52	8.0	12.15	6.9	103.4
	Bullocks	15.0	9.5	-	-	8.0	12.15	12.9	57.4
Toria	Tractor	2.0	26.5	9	52	12.0	12.15	5.6	119.2
	Bullocks	2.0	26.5	9	-	12.0	12.15	10.6	72.2
Rabi Fodder	Tractor	15.0	34.0	-	124	6.4	12.15	-	192.0
(Sale)	Bullocks	15.0	34.0	-	-	6.4	12.15	350.0	418.0
Rabi Fodder (Bullocks)	Bullocks	15.0	34.0	-	-	6.4	12.15	-	67.6
Rice - IRRI	Tractor	16.0	53.0	18	57	16.0	12.15	13.7	185.8
	Bullocks	16.0	53.0	18	-	16.0	12.15	33.7	148.8
Rice - Basmati	Tractor	11.5	43.5	18	57	16.0	12.15	8.7	166.8
	Bullocks	11.5	43.5	18	-	16.0	12.15	18.7	119.8
Maize - Desi	Tractor	5.4	43.5	9	57	9.6	12.15	8.3	145.0
	Bullocks	5.4	43.5	9	-	9.6	12.15	18.3	98.0

Maize - Hybrid	Tractor	5.4	60.5	27	57	9.6	12.15	12.1	184.0
	Bullocks	5.4	60.5	27	-	9.6	12.15	27.1	142.0
Kharif Fodder (Sale)	Tractor	9.0	43.5	-	55	6.4	12.15	-	126.0
	Bullocks	9.0	43.5	-	-	6.4	12.15	225.0	296.0
Mung	Tractor	6.0	9.5	-	50	8.0	12.15	5.7	91.3
	Bullocks	6.0	9.5	-	-	8.0	12.15	9.7	45.3
Kharif Fodder (Bullocks)	Bullocks	9.0	43.5	-	-	6.4	12.15	-	71.0
Cotton	Tractor	8.0	60.5	27	44	16.8	12.15	17.6	186.0
	Bullocks	8.0	60.5	27	-	16.8	12.15	25.0	149.6
Sugarcane (Gur)	Tractor	240.0	180.5	27	116	32.8	12.15	68.6	677.0
	Bullocks	240.0	180.5	27	-	32.8	12.15	98.6	591.0
Cotton/Wheat	Tractor	30.0	127.0	27	106	27.2	24.30	35.3	376.8
	Bullocks	30.0	127.0	27	-	27.2	24.30	65.0	300.5
Rice/Wheat	Tractor	38.0	119.5	18	126	26.4	24.30	30.0	382.0
	Bullocks	38.0	119.5	18	-	26.4	24.30	67.0	393.0
Maize/Wheat	Tractor	27.4	127.0	27	119	20.0	24.30	27.0	372.0
	Bullocks	27.4	127.0	27	-	20.0	24.30	63.0	289.0

the basic model have therefore been drawn from the wheat-cotton area of the Punjab. In the basic model, the farm size is assumed to be 50 acres. Solutions are obtained for tractor and bullock technology and under a perennial canal system with and without a tubewell. In addition to investigating tractors, threshers[1] are also examined.

Tractor Versus Bullocks

Cropping Intensities

Table 5.5 gives the model and survey results regarding the cropping intensities on tractor and bullock

TABLE 5.5.--Cropping Intensities for Tractor and Bullock Farms in Model and Survey Results.

Technology	Irrigation System (Canal Irrigation Plus)	50-Acre Farm	
		Model Results	Survey Results
Bullocks	No Tubewell	99.3	112.5
Tractor	No Tubewell	94.3	108.8
Bullocks	Tubewell	144.2	129.1
Tractor	Tubewell	187.0	
Bullocks + Tractor	Tubewell	192.0	162.0

[1]Threshers, however, were not studied in our field survey. Therefore, we have no empirical evidence to compare with the model results.

farms under different irrigation systems. It will be noted that for cropping intensity differences between tractor and bullock farms, both with and without tubewell, the model corroborates the survey results. In both cases the tractor without a tubewell has no influence on cropping intensities. This situation is indicative of the saline groundwater area discussed in Chapter IV.

With a tubewell, tractor power leads to substantially higher cropping intensity on the tractor compared to the bullock farms. In one respect, however, the model results differ from the survey: the cropping intensity in the tubewell area is significantly higher, especially on the tractor farm, for the model as compared to the survey. This divergence supports the hypothesis advanced in Chapter IV, that in the sweetwater wheat-cotton area the tractor farms had not adequately exploited the cropping intensity potential by adopting the non-conventional "wheat after cotton" crop rotation. As indicated in Table 4.4, the change had been initiated by some but as yet not adopted by most of them. It is mainly through this crop rotation that the model farm operator achieves relatively higher intensities. (Table 5.6).

Cropping Patterns

The model results given in Table 5.6 show that, both with and without a tubewell, the cropping pattern on the tractor farms has a higher proportion of high value crops

TABLE 5.6.--Cropping Pattern Percentages for Tractor and Bullock Farms from Model Results.

Crops	With Tubewell			Without Tubewell	
	Tractor + Bullocks	Tractor	Bullocks	Tractor	Bullocks
Wheat	43.0	40.4	27.6	40.7	29.7
Rabi Fodder	4.0	-	5.8	-	8.6
Toria	-	-	-	-	-
Gram	-	11.5	31.4	-	1.0
Kharif Fodder	8.0	4.4	5.8	9.0	8.6
Rice	-	-	-	-	-
Maize	-	5.9	23.1	9.5	31.4
Mung	2.5	12.6	-	9.5	-
Cotton	32.5	21.9	2.0	24.5	14.2
Sugarcane	3.0	3.3	4.3	6.8	6.5
	100.0	100.0	100.0	100.0	100.0

of wheat and cotton as compared to the bullock farms. The explanation lies in their harvest-sowing overlapping and consequential seasonal peak power constraint in the month of May and in November/December.[1] The tractor farm in the model was able to overcome the seasonal peak power constraint of these high value crops but the bullock power farm could not. Bullock farms, therefore, grow relatively more

[1]For further clarification see the sowing and harvest calendar of wheat and cotton in Table 4.3

maize and gram which are low value[1] but have less urgent seasonal power requirements. Maize is a short-season (July-October/November) summer crop to which the farm operator can turn when constrained in cotton sowing. Similarly, the winter crop of gram is chosen by the model because its early harvest in March avoids the May peak power constraint.

The survey results analyzed earlier indicated cropping pattern differences between the tractor and bullock farms analogous to the model. For example, the tractor farms in the non-tubewell area had relatively higher percentages of their cropped area under cotton as compared to bullock farms, which had relatively more gram and toria (Table 4.13). In the tubewell area, however, the high value crops in which the tractor farms relatively exceeded were fruits and vegetables rather than cotton and wheat.

Shadow Prices[2] of Fixed Resources

The shadow prices indicated by the programming model identify the type of resource constraints faced by a farm operator under different farm power technologies and systems of irrigation. The marginal value products of different resources when compared with their unit costs

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[1]For net revenue per acre of maize and gram as compared to wheat and cotton see Table 5.3.

[2]In the primal solution of the L.P. problem, the "dual" of fixed resources represents their shadow prices or the marginal value products.

show the economic pulls that the model farmer feels under different situations.

Table 5.7 presents the shadow prices (MVPSS) per acre of land, tractor hour, acre inch of water, and a bullock pair hour. The shadow prices indicate that without a tubewell, the bullock farm operator faces both water and bullock power constraints. The reason for the water constraint is obvious, but the shortage of bullock power in this low intensity area (Table 5.5) needs explanation. The scarcity of bullocks appears in the month of May. In this month the bullock power is needed for the threshing of wheat and sowing of cotton, the two major crops accounting for more than 50 per cent of the total cropped acreage. The sowing of the summer fodder also takes place in this month.

A comparison of the bullock pair hour MVP of rupees 10 (Table 5.7) to a unit cost of roughly rupee 1 per hour[1] indicates a high profitability of additional bullock hours. There does not exist a market in the Punjab where bullock services can be hired. This, however, indicates the intensity of demand for power to handle the seasonal peaks.

The water constraint appears during the months of September to November, when the winter crops are sown. (They account for more than 60 per cent of the total cropped

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[1]A regular market does not exist but rupee 1 per hour is generally used for cost calculations.

TABLE 5.7.--Shadow Prices (in Rs.) of Resources Fixed to the Farm.

Resources	With Tubewell						Without Tubewell			
	Tractor and Bullocks		Tractor		Bullocks		Tractor		Bullocks	
	Months	Shadow Price	Months	Shadow Price	Months	Shadow Price	Months	Shadow Price	Months	Shadow Price
Land (price per acre)	Apr	133	Sept	54	Aug	54	-	-	-	-
	Aug	88	Nov-1	111	Oct-1	112				
	Nov-1	99			Nov-1	6				
	Dec	69								
Tractor (price per hour)	May	32	May	53	N/A		-	-		N/A
			Nov-1	14						
Water (price per acre inch)	-	-	-	-	-	-	Oct-1	34	Sept	22
							Oct-2	103	Oct-2	15
							Nov-1	43	Nov-1	19
							Dec	92	Nov-2	16
Bullocks (price per pair hour)	May	5	N/A		May	10	N/A		May	10
					Sept	0.2				
					Nov-2	1.6				

area--Table 4.13.) The MVP per hour of water is quite high[1] as shown in Table 5.7. However, there are no sources for acquiring additional water. Canal water supplies cannot be supplemented due to the saline groundwater, and the scarcity is felt by everyone at the same time of the year.

With the introduction of tractors in the area without tubewell, the power constraint in the month of May is removed (Table 5.7). This enables the farm operator to change his cropping pattern, as shown in Table 5.6, by bringing a higher percentage of his area under wheat and cotton. As shown earlier, the tractor farm operator cannot increase the total crop acreage because the water constraint faced previously is further accentuated and the supplies are limited by what is available from canal delivery.

The situation is different in areas having sweet groundwater since a tubewell can be installed to supplement the water supplies available from canals. The results of the model indicate (Table 5.7) that the bullock farm operator in this area, evidently not facing a water constraint, is confronted by bullock power limitation and land scarcity. The bullock power shortage now appears both in the month of May and in November (MVP = Rs. 1.2). This is due to differences in the bullock power demand of the major winter and summer season crops. While the winter crops need

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[1]In tubewell areas water is sold at Rs. 3 per hour.

bullock power for both sowing and harvest operations, the summer crops use it for only sowing purposes.

It is evident from the above that the need for additional power increases with the availability of supplementary water from tubewells. When tractor power is introduced in this situation, the bullock power shortage in the months of May and November is transformed into a tractor power shortage in the same months. The intensity of this shortage is indicated by the MVP of Rs. 53 and 14 per hour of tractor in the months of May and November, respectively.[1] As shown earlier (Tables 5.5 and 5.6), tractor power leads to substantially higher cropped acreage and a change in cropping patterns and consequently creates further power needs. During the field survey it was observed that most of the tractor farmers were also keeping bullocks (Table 4.15). Although it will shortly be seen that the purchase of a thresher would have been more profitable than keeping bullocks, the model results indicate that even the latter choice makes economic sense. It will be noticed from Tables 5.5 and 5.6 that when the bullock supplements the tractor, it further increases cropping intensity and changes the cropping pattern in favor of high value crops.

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[1]The tractor custom hiring rate is about Rs. 12 per hour.

Net Farm Revenue

The previous discussion indicated the effect of tractor power and/or tubewell water on the level of cropping intensity and the cropping pattern. These effects are ultimately reflected in the net farm revenue. Table 5.8 shows the net revenues obtained by different types of farms.

TABLE 5.8.--Net Farm Revenue (in Rs.) for Tractor and Bullock Farms from Model Results.

Technology	Irrigation System (Canal Irrigation Plus)	Net Farm Revenue (Gross Receipts - Variable Costs) for 50-Acre Farm
Bullocks	No Tubewell	14,531
Tractor	No Tubewell	18,293
Bullocks	Tubewell	18,473
Tractor	Tubewell	30,928
Tractor + Bullocks	Tubewell	33,371

It is evident that the lowest net revenue is on a bullock farm without tubewells. The addition of a tractor or a tubewell increases the net revenue by almost equal amounts (about 3.5 thousand rupees in both cases). The mechanism through which the additional revenue is generated, however, differs between the two cases. Whereas the addition of the tractor changes the cropping pattern from low to high value crops, the tubewell enables the bullock farmer to have a higher cropping intensity (Tables 5.5 and 5.6). The biggest increase in net revenue is achieved with a combination of a tractor and a tubewell. Net revenue is even higher if bullocks are retained. The highest revenue is achieved when both higher cropping intensity and a high value cropping pattern can be pursued.

Tractor with Thresher Versus Bullock with Thresher

The farm equipment assumed in the basic model was changed by adding a thresher. The model results after this change are given in Tables 5.9 through 5.12. As expected, without a tubewell the acquisition of a thresher is of no value to the tractor farm. The cropping intensity, cropping pattern, and net revenue are not affected. The reason is that the constraining factor for the tractor farm continues to be water and not power. However, for the bullock farm without a tubewell, a thresher brings all the benefits that would have been brought by the tractor. Moreover, the capital investment required is substantially smaller. The cropping pattern changes in favor of high value crops and as a result brings net revenue almost equivalent to a tractor (Table 5.12). The reason is that the power constraint appears only in the month of May and the wheat thresher, by easing the bullock power for cotton sowing, accomplishes almost the same results as tractor replacing the bullocks.

TABLE 5.9.--Cropping Intensities with Thresher Added for Tractor and Bullock Farms from Model Results.

With Tubewell				Without Tubewell			
Tractor		Bullocks		Tractor		Bullocks	
Without Thresher	With Thresher	Without Thresher	With Thresher	Without Thresher	With Thresher	Without Thresher	With Thresher
187	200	144.2	152.6	94.3	94.3	99.3	117.8

TABLE 5.10.--Cropping Pattern Percentages with Thresher Added for 50-Acre Tractor and Bullock Farms from Model Results.

Crops	With Tubewell				Without Tubewell			
	Tractor		Bullocks		Tractor		Bullocks	
	Without Thresher	With Thresher	Without Thresher	With Thresher	Without Thresher	With Thresher	Without Thresher	With Thresher
Wheat	40.4	48.4	27.6	48.1	40.7	40.7	29.7	32.8
Rabi Fodder	-	-	5.8	5.5	-	-	8.6	7.2
Toria	-	-	-	-	-	-	-	-
Gram	11.5	-	31.4	-	-	-	1.0	-
Kharif Fodder	4.4	4.1	5.8	5.5	9.0	9.0	8.6	14.7
Rice	-	-	-	1.6	-	-	-	-
Maize	5.9	-	23.1	8.4	9.5	9.5	31.4	20.2
Mung	12.6	8.9	-	-	9.5	9.5	-	-
Cotton	21.9	35.5	2.0	26.8	24.5	24.5	14.2	19.7
Sugarcane	3.3	3.1	4.3	4.1	6.8	6.8	6.5	5.4
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 5.11.--Shadow Prices (in Rs.) of Fixed Farm Resources with Thresher Added for 50-Acre Tractor and Bullock Farms.

Resources	With Tubewell				Without Tubewell			
	Tractor + Thresher		Bullock + Thresher		Tractor + Thresher		Bullock + Thresher	
	Month	Price	Month	Price	Month	Price	Month	Price
Land (price per acre)	July	88	Oct-1	346	-	-	-	-
	Nov-1	401						
Tractor (price per hour)	May	32	N/A		-	-	N/A	
Water (price per acre inch)	-	-	-	-	Oct-1	34	Oct-1	183
					Oct-2	103	Oct-2	67
					Nov-1	43	Nov-1	47
					Dec	92	Nov-2	138
Bullocks (price per pair hour)	N/A		May	1.8	N/A			
			Nov	1.5				
			Dec	7.2				

TABLE 5.12.--Net Farm Revenue (in Rs.) with Thresher Added for 50-Acre Tractor and Bullock Farms from Model Results.

With Tubewell				Without Tubewell			
Tractor		Bullocks		Tractor		Bullocks	
Without Thresher	With Thresher	Without Thresher	With Thresher	Without Thresher	With Thresher	Without Thresher	With Thresher
30,928	38,360	18,473	28,446	18,293	18,819	14,531	18,221

In the tubewell area, the model provides best results when the thresher is combined with a tractor. Cropping intensity increases to 200 per cent; cropping pattern improves in favor of high value crops and leads to the highest net revenue as compared to any other situation. On a bullock farm, the thresher has a limited influence in raising the total cropped acreage. As shown in Table 5.9, cropping intensity only increases from 144 to 152 per cent. The reason for this limited response is that the power constraint in the tubewell area is binding both at the sowing and harvest ends of the wheat crop activity. The thresher obviously overcomes the power shortage at the harvest time but has no influence at the sowing end. The thresher, however, does make a substantial contribution to net farm revenue through changing cropping pattern in favor of high value crops. As shown in Table 5.12, the net revenue on a bullock farm with a thresher, though much below that of the tractor farm with a thresher, is quite close to the tractor farm without a thresher.

The Rate of Return on Mechanization in the Pakistan Punjab

The benefit side of mechanization was discussed in detail in the previous section. In this section the cost of mechanization is combined with the benefits to calculate the rate of return for the private farm operator. The analysis in the previous section identified both the higher cropping intensity and the high value cropping pattern on tractor compared to bullock farms as potential sources of economic benefits from mechanization. The higher yields per acre of different crops on the mechanized farms is another possible source. The yield effect has, however, been controversial.[1] The survey results provide no consistent evidence of higher yeilds on the tractor farms. Therefore, the basic model assumes that the tractor and bullock farms have identical yields and inputs per acre of different crops except for the source of power. If, in actual practice, the tractor farms, using similar inputs, do get higher yields, then, to that extent, the rate indicated by the model would be the lower bound.

The rate of return r is given by the expression:

$$M = \sum_{t=1}^{8} \frac{R}{(1 + r)^t}$$

where:

M is the net capital cost of tractor and equipment

= (total capital cost of tractor and equipment) - (total cost of the bullocks and equipment replaced)

= Rs. 32,340 - Rs. 6400 = 25,940[2]

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[1]See 6, pp. 274-277, and 37, p. 128.

[2]It is assumed that tractor replaced four pairs of bullocks on a 50-acre farm. For details of tractor and bullock costs see Table 5.13.

TABLE 5.13.--Cost of Tractor and Bullock Technology Packages.

I. Tractor and Equipment

		Market Price[1] 1970-71 (Rs.)
1.	Tractor 45 H.P.	17,500
2.	Cultivator/tiller (9 tines)	1,610
3.	Mouldboard Plow	2,500
4.	Wheat drill (13 tine with fertilizer attachment)	3,730
5.	Cotton Planter	3,000
6.	5-ton trailer	4,000
7.	Total (1-6)	32,340
	Thresher	5,000
	Fuel and lubricants per gallon	3.3

II. Bullocks and Equipment[2]

		Life (Years)	Price (Rs.)	Salvage Value after 8 Years (Rs.)	Cost for 8 Years
1.	One pair of bullocks	12	1800	600	1200
2.	One set of implements	10	500	100	400
3.	Total (1-2)		2300	700	1600

[1]The market prices were taken from Lawrence (41) and Rana Tractors Limited, Lahore. The foreign component is valued at Rs. 4.7 = $1.00.

[2]Computed from Naseem (45, Table v.6).

R is the annual differential revenue = (Total annual net[1] revenue on tractor farm) - (Total annual net revenue on bullock farm) = Rs. 30,928 - 18,473 = 12,455[2]

t is the time period over which the benefits of mechanization would accrue. It is assumed here that the mechanization package would last for eight years with zero salvage value at the end of the 8th year.

Rate of Return on Tractor Mechanization

This section considers the rate of return on tractor mechanization on the basis of the farm input and output prices that prevailed in the Punjab markets during the year 1970-71. The rate of return calculated on a farm size of 50 acres, as assumed in the basic model, is given in Table 5.14.[3] As expected, the rate of return is very sensitive to the system of irrigation. Without a tubewell, where water availability is limited by the supplies from the canal, the rate of return is only 3 per cent which is not

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[1]Net revenue = gross receipts minus variable costs.

[2]For details of net revenue on the tractor and bullock farm see Table 5.8.

[3]The calculations of the internal rate of return are based on the usual assumption that technology and the prices of inputs and outputs will remain constant over the lifetime (8 years) of tractor.

TABLE 5.14.--The Rate of Return on Tractor Mechanization in the Punjab--All Bullocks Disposed of, Market Prices 1970-71.

Irrigation	Farm Size (Acres)	Additional Cost: (Tractor and Equipment)[a] - (Bullocks and Equipment)[a] (Rs.)	Additional Revenue: (Tractor - Bullock)[b] (Rs.)	Rate of Return (Per Cent)
Canal Plus Tubewell	50	25,940	12,455	46
Canal Only	50	25,940	3,762	3

[a]For further detail see Table 5.13. For a 50-acre farm, four bullock pairs are assumed.

[b]For details see Table 5.8.

enough even to pay the interest of 9 per cent on tractor loans charged by the Agricultural Development Bank of Pakistan.

When canal irrigation is supplemented with tubewell water, the tractor investment brings a return of 46 per cent per annum. Thus, in the tubewell areas the farmers have a net benefit of 37 per cent (46-9) after paying interest on the tractor loan. This provides a great economic incentive to mechanize. It is no wonder, therefore, that, as indicated in Chapter II, about 63 per cent of the tractors have been introduced on the farms having both tubewell and canal irrigation.

Although the net benefit of mechanization from field crops cultivation in the canal-irrigated areas without tubewell has been shown to be negative (3-9), still 20 per cent of the tractors up to 1969 are reported to have been introduced in this area (see Chapter II). The explanation of this seemingly uneconomic behavior is given by two likely sources of economic gains not considered in our calculations. These are the benefits of the tractor in claiming the land from tenants for self-cultivation and from using it for transportation purposes. During the survey, both the tenant displacement (see Chapter IV) and the use of tractor for transportation were observed to be quite widespread.

Rate of Return with Bullocks and Thresher in the Tubewell Area

The rate of return calculations discussed above were based on the assumption that the tractor completely replaces the bullocks. This assumption will be relaxed now to consider the effect on the profitability of mechanization when the tractor farm operator continues to keep all his bullocks or has a tractor-thresher package. Table 5.15 gives the rate of return on mechanization under these different situations. The rate falls from 46 to 43 per cent when bullocks are retained with the tractor. But if the tractor is supplemented by a wheat thresher the rate goes up substantially, i.e., from 46 to 63 per cent. During the field survey many tractor farmers were observed to be keeping bullocks instead of replacing them with tractors. The model results indicate that the farmers were not using the most economical package of mechanization.

Rate of Return on Mechanization: Tractor-Thresher Package Replaces Bullock-Thresher

In the above paragraphs the profitability of mechanization was discussed under three situations: (1) tractor replacing bullocks, (2) adding a tractor to bullocks, and (3) tractor-thresher replacing bullocks. The bullock-tractor-thresher sequence of mechanization used in the analysis is based on the field observation in Pakistan. In this section, however, the above sequence

TABLE 5.15.--Rates of Return on Tractor Mechanization in the Tubewell Area With and Without Bullocks and Thresher.

Farm Size	Tractor Only	Tractor + Bullock					
	Rate of Return	Additional Cost	Additional Revenue	Rate of Return	Additional Cost	Additional Revenue	Rate of Return
		Tractor + Bullock + Equipment - Bullock + Equipment	[(T+B) - B]		Thresher + Tractor + Equipment - Bullock + Equipment	[(TR+THR) - B]	
(Acres)	(Per Cent)	(Rs.)	(Rs.)	(Per Cent)	(Rs.)	(Rs.)	(Per Cent)
50	46	32,340	14,899	43	30,940	19,887	63

is altered to bullock-thresher versus tractor-thresher to study the influence on the rate of return to mechanization when the transition takes place from the bullock-thresher package to the tractor-thresher combination.

As explained previously, the basic difference between a thresher and a tractor as sources of additional power is that while the former can be used only on the harvest end, the latter can be used at both sowing and harvest time. As a result the tractor-thresher combination leads to a substantial increase in the net revenue over that of the bullock-thresher package. As shown in Table 5.16, this brings a rate of return of 35 per cent to investment in the tractor.

Employment Effects of Mechanization

The influence of mechanization on employment, as shown in Table 5.17, varies with the system of irrigation and the package of mechanization used. In the canal-irrigated area without a tubewell, employment per cultivated acre decreases when the bullocks are replaced by a tractor. Adding a thresher to the tractor further reduces employment, the reason being that when introduced in this sequence the thresher displaces labor on wheat threshing and winnowing without any positive employment contribution by affecting intensity and cropping patterns. If, however, the thresher is used with bullocks, the labor used increases to 367 man-hours per cultivated acre compared to 344 with bullocks only.

TABLE 5.16.--Rate of Return on Mechanization With Tractor-Thresher Replacing Bullock-Thresher.

Farm Size	Additional Cost	Additional Revenue	Rate of Return
	Tractor + Thresher + Equipment - Bullock + Thresher + Equipment	[(TR+THR) - (B+THR)]	
(Acres)	(Rs.)	(Rs.)	(Per Cent)
50	25,940	9,914	35

TABLE 5.17.--Employment Effects of Mechanization in the Pakistan Punjab, Model Results.

Technology	Manhours of Labor Employed Per Cultivated Area (50-Acre Farm)					
	Canal Irrigation with Tubewell			Canal Irrigation		
	Hired	Family	Total	Hired	Family	Total
Bullocks only	268	131	399	213	131	344
Tractor only	280	122	402	153	103	256
Tractor and bullock	380	130	510			
Tractor and thresher	329	114	443	139	103	242
Bullocks and thresher	305	134	439	227	130	357

Besides favorable employment effects, thresher use, as noted earlier, was also the best form of mechanization in areas without tubewell water, from the farm income point of view.

In the tubewell area all forms of mechanization, i.e., tractor alone, tractor plus thresher, bullocks plus tractor, and bullocks plus threshers, lead to increase in employment as compared to bullock cultivation. The survey results also indicated positive employment effects in the area (Table 4.23). With no water constraint, mechanical power through its cropping pattern and intensity effects tends to create more jobs than it displaces. The model results indicate that from an employment point of view the tractor plus bullocks is the best combination, but, as stated earlier (Table 5.15) the tractor plus a thresher is most appropriate for farm income. The combination involving bullocks has an employment bias because of the relative labor intensity of the fodder crops emerging from multiple harvest operations.

The micro level conclusions about the employment effects of mechanization given in Table 5.17 are expected to hold at the macro level. The reason is that the increased overall production of the major food grain and cash crops is not likely to have any significant effect on the price received by the farmers. In the case of food grains, imports provide a substantial[1] part of the domestic consumption. Thus, increase in the domestic production of foodgrains will mainly substitute for imports. Therefore, the effect of increased domestic production on the prices of foodgrains supplied in the market will be negligible. Regarding export crops, mainly cotton, Pakistan produces such a small proportion of the world supply that she faces an almost completely elastic demand curve.

Summary

The results of the basic solution of the linear programming model show that without a tubewell tractor power has no influence on cropping intensity but with a tubewell it leads to substantially higher intensity (187 per cent) compared to the bullock farms (144 per cent). Cropping patterns on the tractor farms have a higher proportion of high value crops of wheat and cotton as compared to the bullock farms. The net farm revenue is lowest (Rs. 14,000) on a bullock farm. The addition of a tubewell or the replacement of the bullocks by a tractor increases the net revenue by almost equal amounts (i.e., about 3.5 thousand). Combining the tractor and a tubewell achieves the greatest increase (Rs. 15,000) in the net farm revenue.

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[1]Even after the Green Revolution, Pakistan is importing about one and a half million tons of foodgrain this year. Roughly a million tons has been the historical yearly average import for more than a decade in the past.

Without a tubewell, the thresher has no influence when added to a tractor, but when added to bullocks, a thresher gives results equivalent to a tractor replacing the bullocks. With a tubewell, however, the thresher-tractor combination brings substantially higher net revenue (Rs. 38,000) as compared to thresher-bullock (Rs. 28,000). Without a tubewell, the rate of return on tractor mechanization on a 50-acre farm is 3 per cent, but with a tubewell it is 46 per cent per annum. If the tractor farmer uses a thresher, the rate increases to 63 per cent. The rate, however, falls to 35 per cent when the tractor-thresher package replaces the bullock-thresher combination.

Without a tubewell, labor use per acre decreases with a tractor but increases with thresher mechanization. With a tubewell, however, all combinations of bullock, tractor, and thresher increase employment as compared to bullocks alone.

The next step in the analysis will be to test the results of the basic model with respect to variation in the size of the farm, the prices of inputs and outputs, and the tubewell water as shown in Chapter VI.

CHAPTER VI

SENSITIVITY ANALYSIS OF THE PROGRAMMING MODEL RESULTS

In the preceding chapter, results of the basic solution of the programming model were analyzed. The present chapter investigates the influence on the profitability of mechanization of three factors believed to be critical in the process. These factors are (1) the size of the farm, (2) the prices of the major inputs and outputs, and (3) constraints on water that a tubewell farmer would be permitted to pump.

Size of the Farm and Rate of Return on Mechanization

In any discussion of economics of mechanization, the size of the farm holds a prominent position (see 6, 35, and 37). Due to the lumpiness of the tractor, the rate of return on tractor investment tends to change with the size of the farm. The analysis in the preceding chapter assumed a farm size of 50 acres. In this section the size of the basic farm will be increased and decreased by 50 per cent to study the influence of farm size on rate of return on mechanization.

Table 6.1 shows the rate of return on farms of 25, 50, and 75 acres. The rate tends to increase as the size

TABLE 6.1.--The Rate of Return[1] on Tractor Mechanization at Market Prices, 1970-71. (No bullocks retained.)

Size of the Farm (Acres)	Per Cent Rate of Return	
	With Tubewell	Without Tubewell
25	32	negative
50	46	3
75	41	10

[1]See Chapter V for the formula, Table 5.13 for the tractor and bullock costs, and Appendix C for the net farm revenue. Bullock pairs are assumed at four at 50 acres and vary proportionately with the size of the farm.

of the farm expands upward from 25 acres. The pattern of change in the rate of return in relation to the farm size, however, differs between the tubewell and non-tubewell farms. Without a tubewell, the rate starting from negative at 25 acres continues to increase up to 75 acres. But with a tubewell, the rate declines between 50 and 75 acres. These results suggest that the system of irrigation is an important factor influencing the optimal size of the farm for tractor cultivation. With a tubewell, the optimum size lies between 50 and 75 acres, while it is at 75 or above without a tube-well. As shown earlier, the additional water permits a higher cropping intensity on the tubewell as compared to the non-tubewell farm. Thus, on a tubewell farm it is both the intensive and extensive cultivation that use tractor capacity, while it is only the latter in the case of non-tubewell farms.

The analysis in the above paragraphs assumed mechanization consisting of only a tractor. Now this assumption is relaxed to study the influence of mechanization packages consisting of (1) tractor plus bullocks and (2) tractor plus thresher. Table 6.2 gives the rate of return on different mechanization packages on a tubewell farm.

TABLE 6.2.--Rates of Return[1] on Tractor Mechanization on a Tubewell Farm, with and without Bullocks and Thresher.

Farm Size (Acres)	Per Cent Rate of Return		
	Tractor Only	Tractor + Bullocks	Tractor + Thresher
25	32	18	27
50	46	43	63
75	41	48	68

[1]See Chapter V for the formula, Table 5.13 for the equipment costs of bullocks verses different forms of mechanization, and Appendix C for the net farm revenue.

The change in the rate of return with the size of the farm indicates that with the tractor alone, as discussed earlier, the economies of scale are exhausted between 50 and 75 acres. But when tractor capacity is supplemented by bullocks or a thresher, the economies are present up to 75 acres. Thus, in the last two cases, the optimum size of the farm will be at 75 acres or above. These results show that the optimum size of the farm varies with the package of mechanization.

Farm Size and Employment

The employment effect of mechanization varies with the type of the mechanization. As shown in Table 6.3 the labor use per acre in the tubewell area tends to decline as the size of the farm increases from 25 to 75 acres for most types of mechanization. At 75 acres, however, the trend reverses in the case of tractor plus bullocks and stabilizes in the case of bullocks only. The explanation for these results lies in the fact that while bullock numbers change proportionately with the size of the farm, the fixed tractor and thresher capacity gets distributed over larger and larger areas. These capacity limitations begin to affect the level of cropping intensity and patterns and, therefore, employment.

Input-Output Price Distortion and Profitability of Mechanization

The rates of return on mechanization discussed previously reflect a situation where the individual farm operator faced the prices of inputs and outputs prevailing in the domestic market in Pakistan during 1970-71. The review of literature in Chapter II, however, indicated that

TABLE 6.3.--Size of the Farm and Employment Effects of Mechanization in Tubewell Areas of the Punjab.

Size of the Farm (Acres)	Man Hours Per Acre											
	Bullocks Only			Tractor Only			Tractor + Bullocks			Tractor + Thresher		
	Hired	Family	Total	Hired	Family	Total	Hired	Family	Total	Hired	Family	Total
25	195	234	429	335	184	519	315	214	529	307	184	491
50	268	131	399	280	122	402	380	130	510	329	114	443
75	307	92	399	233	79	312	433	92	525	326	84	410

some of the market prices critical to mechanization do not reflect true scarcity and that correction of the price distortion might change the rate of return drastically. In this section agricultural machinery, equipment and fuel on the cost side, and internationally traded agricultural commodities on the benefit side will be priced at the world market level to study their influence on the rate of retrun to mechanization. The underlying assumptions and the calculations at world market prices are shown in Tables 6.4 and 6.5.

The rate of return to the private tractor farm operator facing the world market or social prices of agricultural machinery and commodities is given in Table 6.6.

It will be noted that without a tubewell the rate of return at world market prices is negative. With a tubewell, however, the rate, though less than at domestic prices, still remains very high, i.e., 32 per cent. Even if the rate on borrowing capital were increased from 9 to 15 per cent[1] to reflect its scarcity value, the private farm operator would still have net benefits of 17 per cent per annum.

Given the nature of distortion in the prices of agricultural machinery and commodities as indicated in

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[1]Rates varying from 10 to 15 per cent have been used as social cost of capital against the rate of 9 per cent charged by Agricultural Development Bank of Pakistan. Lawrence (41) uses 15 per cent.

TABLE 6.4.--Cost of Mechanical and Bullock Technology Package.

I. Mechanical Technology

	Domestic Market Prices[1] (Rs.)	World Market Prices[2] (Rs.)
Tractor 45 H.P.	17,500	29,550
Cultivator/tiller (9 tines)	1,610	2,473
Mouldboard plow	2,500	3,840
Wheat drill (13 tines with fertilizer attachment)	3,730	6,536
Cotton planter	3,000	4,608
5-ton trailer	4,000	5,072
Total	32,340	52,079
Thresher	5,000	6,340
Fuel and lubricants per gallon	3.30	1.90

II. Bullock Technology[3]

	Life (Years)	Price (Rs.)	Salvage Price After 8th Year	Cost for 8 years
One pair of bullocks	12	1800	600	1200
Implements set	10	500	100	400
Total		2300	700	1600

[1]The market prices were taken from Lawrence (41) and Rana Tractors Limited, Lahore. Here the foreign exchange component is valued at Rs. 4.7 = $1.

[2]World market prices exclude all taxes and value foreign exchange component at Rs. 11 = $1. Most of the items have different foreign exchange components.

[3]Computed from Naseem (45, Table V.6).

TABLE 6.5.--Prices of Internationally Traded/Import Competing Agricultural Crops.

Crops	Domestic Market Prices[1] (Rs.)	World Market Prices[2] (Rs.)
Wheat	17	20
Rabi oil	24	58
Maize	15	19
Cotton	50	70
Rice--IRRI (Paddy)	12	22
Rice--Basmati (Paddy)	17	50
Sugarcane (Gur)	40	15

[1]The harvest prices prevailing during 1970-71. Among other things, these prices reflect the government taxation and price policies and the foreign exchange rate of Rs. 4.7 = $1.

[2]These are the prices likely to prevail in the domestic market on the basis of world market prices assuming no taxes and public control over prices and a foreign exchange rate of Rs. 11 = $1. The world market prices were assumed to be the mid-way prices of the minimum and maximum used by Lawrence (42, Table A-8).

TABLE 6.6.--Rate of Return on Mechanization at World Prices[1] Compared with Domestic Prices. (Tractor Only)

Farm Size	Prices	Per Cent Rate of Return	
		With Tubewell	Without Tubewell
50	World	32	negative
50	Domestic	46	3

[1]See Table 6.4 for the equipment costs for Tractor and bullocks and Appendix C for the net farm revenue.

Tables 6.4 and 6.5, respectively, these results of the model for a tubewell farm are not unexpected. On the cost side, the domestic market underprices tractor and equipment by about 38 per cent and overprices fuel and lubricants by about 74 per cent. On the benefit side, all agricultural products are underpriced except sugarcane. The extent of underpricing in the case of cotton, oilseeds, and rice (Basmati) is 29, 59, and 66 per cent, respectively. It is evident that when price distortions are corrected, the changes on the cost and benefit side are compensatory to a large extent. As a result the fall in the net revenue is modest rather than drastic.

Tubewell Water and the Rate of Return on Mechanization

In this analysis of the economics of mechanization, tubewell water has shown itself to be critical. It was seen in the preceding chapter that, whereas the return on investment in tractor mechanization in the non-tubewell farm was low, it was high on the farm having tubewell water. Hence, the sensitivity of the rate of return on mechanization to the quantity of tubewell water needs to be investigated, through the programming model exercises. For this purpose the basic categories of a 50-acre farm cultivated under either tractor or bullock technologies will be used for analysis.

The amount of total water, both canal and tubewell, used by the tractor and bullock farms and the level of their cropping intensities is given in Table 6.7. It will

TABLE 6.7.--The Amount of Canal and Tubewell Water Used by 50-Acre Tractor and Bullock Farms in the Model.

	Tractor	Bullocks	Difference (Tractor-Bullocks)
Cropping Intensity	187	144	
Canal Water (acre inches)	1299	1112	187
Tubewell Water (acre inches)	418	267	151
Total Water	1717	1379	338

be seen that the tractor farm with 43 per cent points higher cropping intensity uses 338 more acre inches, i.e., about 25 per cent, as compared to the bullock farm. It is interesting to note that the additional water used on the tractor farm is not entirely drawn from the tubewell. About 55 per cent of it comes through increased utilization of the fixed water supply from the canal. The amount of canal water available to the tractor and bullock farms is the same, but tractor power, by overcoming the seasonal power constraint, increases the planted acreage and, therefore, off-season utilization of canal water. (The excess water supply in the off-season is usually dumped into such crops as sugarcane, berseem, etc., and thus mostly goes to waste.) This contribution of the mechanical power to increasing the effective canal water supply has not been recognized by most of the earlier researchers on mechanization.[1]

For reasons given earlier, tractor power also increases the utilization of tubewell water. As shown in Table 6.7, the tractor farm utilizes 418 compared to 267 acre inches of tubewell water. Assuming that the recharge of the acquifer per 50 acres is approximately 1200[2] acre inches per annum, the tubewell water withdrawals by both the tractor and bullock farms are considerably below the socially permissible level. These results indicate that it is not the total withdrawals but the supplies made available at critical times that reflect the true value of tubewell. This was further investigated through downward parametric variation of the total tubewell water withdrawals. The maximum withdrawals were varied by 50 per cent at each stop from 400 through 12.5 inches. The rates of return on tractor mechanization at various levels of tubewell water are given in Table 6.8.

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[1]See Bose and Clark (6) and Alvi (1). They emphasize water as a constraining factor limiting ability of the tractor to increase cropping intensity but fail to realize the increase in economic supply of water made possible by the mechanical power.

[2]Gotsch (25, pp. 31-32) assumes 1300 in the Northern Punjab. It is assumed that the recharge will be somewhat less in the Southern Punjab to which the model relates.

TABLE 6.8.--Rates of Return[1] on Mechanization at Various Levels of Tubewell Water on 50-Acre Farms.

	Maximum Permissible Tubewell Water Withdrawals (Acre Inches Per Annum)							
	5760 (418)[a]	400	200	100	50	25	12.5	Nil
Rate of Return	46	46	38	32	23	15	10	3

[1]See Table 5.13 for the tractor and bullocks costs and Appendix C for the net farm revenue.

[a]Actual. In all other cases maximum and actual are the same. The limit on monthly drawal is 480 acre inches.

It is evident from the table that as expected the rate of return does fall when tubewell water is reduced below 400 acre inches. The proportionate fall in the rate, however, is considerably less than that of the water. It is noteworthy that the critical level of tubewell water after which the rate falls below the social cost (i.e., 15 per cent) of borrowing capital is at a very low level, i.e., 25 acre inches.

Summary

The sensitivity analysis indicates that without a tubewell the rate of return on tractor mechanization continues to increase (i.e., from negative to 10 per cent) when farm size varies from 25 to 75 acres. With a tubewell, the rate declines (i.e., from 46 to 41 per cent) between 50 and 75 acres if it is tractor alone but continues to increase up to 75 acres when accompanied by bullocks or a thresher. The use of labor per acre declines with the farm size. At world market prices the rate of return falls to 32 per cent as compared to 46 per cent at domestic prices. Regarding the tubewell water, the rate of return is not affected even when the water withdrawals are reduced to one-third of the socially permissible level of 1200 acre inches per annum per 50 acres farm. The rate of return on mechanization is sensitive to farm size and prices of inputs and output but not to the amount of tubewell water.

CHAPTER VII

CONCLUSIONS, POLICY IMPLICATIONS, AND SUGGESTIONS FOR FUTURE RESEARCH

The object of the study was to investigate the economic and social implications of tractor mechanization in the Punjab province of Pakistan. The study of economics of mechanization involved analysis of its influence on cropping intensity, yields per acre, cropping patterns, and the rate of return on investment in tractor and equipment. The social aspect included the influence of mechanization on employment of labor, tenurial relationships, and structure of the farm. The methodology of the study included: (1) a field survey of a cross-section of fifty farmers in different areas of the Punjab to investigate the existing situation regarding the influence of tractor mechanization on output, employment, and tenurial relationships and (2) the use of a linear programming model developed for the wheat-cotton area in the Pakistan Punjab to examine the rate of return on mechanization and its sensitivity to different economic parameters, such as form of mechanization, size of the farm, prices of inputs and output, and the tubewell water availability, considered to be critical to profitability of mechanization.

Conclusions

The Economics of Mechanization

1. The tractor had no influence on cropping intensity in the saline groundwater areas where tubewell water is not available to supplement the supply from canals because water remains a constraint.

2. Tractor power in the tubewell areas where water is not a constraint made a considerable impact on cropping intensity. Tractor farms had considerably higher intensity level (168 per cent) as compared to bullock farms (144 per cent).

3. In the tubewell areas a widespread market has developed for tractor custom hiring. The tubewell-bullock farms hire tractor services to meet their seasonal peak power requirement. In this way they have been able to achieve cropping intensity close to the tractor farms (161 per cent).

4. With a wheat-rice crop sequence in the tubewell area, the level of cropping intensity on both the tractor (177 per cent) and bullock (162 per cent) farms was higher and the difference between them smaller as compared to the tractor (162 per cent) and bullock (129 per cent) farms in the area with

wheat-cotton as the main crop rotation. The difference in the influence of mechanization emerges from the fact that, whereas the sowing and harvest season do not overlap under wheat-rice, they do overlap under wheat-cotton cropping systems.

5. The tractor farmers in the wheat-cotton area have not yet achieved the double cropping of which they are capable because most of the farmers have not yet accepted the "unconventional" crop rotation of sowing wheat after cotton.

6. In the wheat-cotton area, tractor cultivation led to a cropping pattern relatively dominated by high value crops. This is true both for "with" and "without" tubewell areas.

7. The programming model exercises show that on a 50-acre model farm without a tubewell, the thresher-bullock technology will yield about the same effect on the cropping pattern and net farm revenue as thresher-tractor technology. With a tubewell, however, the thresher-tractor package is far superior to thresher-bullock in terms of higher cropping intensity (200 versus 152 per cent), cropping pattern, and net farm revenue (Rs. 38,000 against 28,000). Even a tractor-bullock combination is better than a thresher-bullock (having net farm revenue of Rs. 33,000 against 28,000).

8. Tractor cultivation has not shown any significant influence on yields per acre. The reason for this was seen to be that (1) the tractor farmers do not have the necessary tractor implements for deep plowing, row crop planting, fertilization, etc.; and (2) the tractor farmers did not have any appraisable difference in the use of other agricultural inputs and improved practices as compared to the bullock farmers.

9. At market prices of inputs and output, the rate of return on tractor mechanization on a 50-acre farm in the wheat-cotton area was very low (3 per cent) without a tubewell but very high (46 per cent) with a tubewell. At social prices the rate of return fell to negative without tubewell and to 32 per cent with tubewell irrigation.

The Social Consequences of Mechanization

1. The family labor per cultivated acre on the tractor farm was lower as compared to the bullock farm. A larger percentage of them, however, were educated. After the tractor, family labor on the tractor farms increased because more of their educated members came to work on the farm.

2. The tractor farms used more (7 per cent) hired labor as compared to the bullock farms.

The structure of the hired labor, however, changed. While the permanent hired labor decreased (19 per cent) on the tracor farms, the use of casual labor increased.

3. Considering both the family and hired labor, tractor farms had less (7 per cent) labor per cultivated area than the bullock farms.

4. Tractor cultivation led to large scale tenant displacement. The operational size of the tractor farms increased through tenant displacement, land renting, and purchase. The tubewell had very similar effects on tenant displacement and the size of the tubewell farm.

Policy Implications

1. The study indicates that no general policy recommendations would be appropriate for the province as a whole. The policy implications differ in different areas. For example, under the present crop technology, tractor as a source of power is profitable on the tubewell farms in the canal-irrigated wheat-cotton areas of the Punjab province but unprofitable without a tubewell. In all cases, however, the conversion from the bullock to tractor leads to tenant displacement. Thus, while in the areas without tubewells the objectives of economic

growth and social justice dictate a common policy against tractor mechanization, these two objectives conflict in the tubewell area. This conflict also appears in the case of tubewell technology (and even high yielding seed varieties), but it is more serious in the case of the tractor because its foreign manufacture provides limited linkages in the non-farm sector and requires a relatively large scale use of foreign exchange resources. For policy purposes the economic and social consequences of mechanization and alternative technologies available need careful reconsideration. For example, in the non-tubewell area, the thresher mechanization has the same influence on the cropping pattern and net farm revenue as the tractor. Besides being less costly than the tractor, the thresher has more indirect benefits in the form of greater employment on the farm and stronger linkages with the off-farm economy because of its domestic manufacture. In the tubewell area, however, the adoption of the thresher instead of the tractor involves foregoing some opportunities in the form of higher productivity which needs to be considered against the other benefits.

2. Correcting the price distortions has often been recommended as a policy instrument to squeeze out

the private profits from mechanization and thereby control its adoption by the farmers. This study shows that such a policy may not be effective in some situations. For example, policy measures designed to correct the factor and output prices and interest rate distortions in Pakistan will not have any significant effect on the profitability of tractor mechanization to a tubewell farmer in the wheat-cotton areas of the Punjab province. Therefore, some other policy instruments would need to be used if policy makers decide to influence the pace or form of mechanization.

3. It will be noticed that besides water and power, the sowing and harvest calendar of the major winter crop, wheat, and summer crops, cotton and rice, is an important determinant of the double cropping possibilities. Historically, for example, when the sowing season of the traditional wheat was mainly from early October to early November, little wheat could be sown after cotton, which was still in the field at that time. The development of new seed varieties with sowing season extending over most of December has created the double cropping opportunity by making it possible to sow wheat after cotton. As yet, the intervening time between the two crops is so short that the bullock power has

limited capability and therefore tractor power is needed to adequately exploit the double cropping potential. An alternative, at least a partial one, to tractor power seems to be the investment in agricultural research to further shorten the growing seasons of wheat and especially cotton. Depending on the time period that can further be generated between the harvest and sowing seasons of these two crops, research in this area could offset the speed advantage of the tractor and permit higher cropping intensity by bullock power. An example is available from the wheat-rice area surveyed in the Punjab where late sowing wheat and early maturing IRRI rice varieties have enabled the bullock farmers to achieve a cropping intensity of 162 against 177 per cent on the tractor farms.

4. Technical change, as mentioned earlier, is critical for agricultural modernization. For optimum results, however, the change in technology mostly involves a bundle of inputs that should be introduced together. The results of our survey in the Pakistan Punjab show that, in the process of technological transformation, the farmers in general have picked up the most profitable input and failed to use the full package. The tractor farmers, for example, have purchased the tractor but not the necessary

equipment for deep plowing, row crop sowing, and fertilization; they have mechanized but have not made any significant headway in the use of improved agricultural inputs and practices as compared to the non-mechanized farmers. It was also noticed that on both the mechanized and non-mechanized farms, while new seed and tubewells have spread very widely, the inputs and practices--e.g., the quantity and combination of fertilizers, sowing method, agricultural implements, even seed selection and treatment, hoeing, and weeding, etc.--have lagged behind. These results emphasize the importance of extension services in the process of agricultural growth through technical change. In the extension programs much more emphasis needs to be given than that previously given to persuading the farmers to make use of the broader package of inputs. In the case of tractor mechanization, a direct action could be taken by tying the purchase of the necessary implements with that of the tractor and providing the necessary finances through loans. The extension services should also focus on breaking the farmer's resistence to adopt the new crop rotation by sowing wheat after cotton.

5. The agricultural growth pattern indicated by this study is such that, within the canal-irrigated areas

of the Punjab, agricultural intensification in terms of double cropping is limited to those areas where supplementary water is available from tubewells. Due to water constraint, the non-tubewell areas (having saline groundwater) have almost no opportunity of participating in higher cropping intensities. With continution of the existing pattern imbalanced growth between the tubewell and non-tubewell areas is inevitable. The results of the programming model exercises indicate that it is not the overall shortage of water but its scarcity at the critical sowing season which limits intensity level in non-tubewell areas. As indicated in Table 8.1, provision of additional water by tubewells in the sweet-groundwater areas increases

TABLE 7.1.--Effect of Additional Tubewell Water on Utilization of Canal Water, for a 50 Acre Bullock Farm.

Source of Water	Water Used in Acre Inches		
	Without Tubewell	With Tubewell	Difference (With - Without)
Canal	987	1103	116

utilization of the canal water. The reason is that the additional water at the sowing time enables the farmer to plant a crop which utilizes the previously surplus water in the offseason. In the past when river waters were unregulated, it was not possible to provide such additional water in the saline groundwater areas. With the construction of reservoirs in the upper reaches of the rivers in Pakistan, their waters are now being controlled. The regulated river waters over seasons open up the possibility of meeting the critical seasonal demand for additional water in the non-tubewell areas and thus permitting agricultural intensification. Diversion of some canal water from tubewell to the non-tubewell areas needs consideration for providing balanced growth opportunities to the two zones.

Future Research

1. The results of this study show that the most serious social effect of mechanization so far, both in the form of tractor and tubewell, has been in terms of large scale tenant displacement. The immediate question in need of research is: Where have the ejected tenants gone? Have they migrated to cities or adjusted within the rural economy? What has been the process and costs of adjustment and what is their present position versus tenant cultivators? The answers to such questions will indicate the magnitude of the indirect cost of mechanization which should be an important variable for consideration in any decision on mechanization policy.

2. Although tractor mechanization had a positive net effect on the total labor hired, the structure of the labor force changed whereby the permanent hired labor decreased. Research is needed to determine where the displaced permanent labor has been absorbed.

3. Another area in need of research is the supply position of the permanent hired labor. During our field survey in the Punjab most of the farmers indicated that it was difficult to get permanent labor but casual labor was easily available. The main reason for the shortage as given by the farmers was migration to cities due to higher wages, fixed working hours, and better working conditions --with which the farmers cannot compete. The importance of the landless agricultural laborers has been rather small in the Pakistan rural economy. They constituted about 8 per cent of the total farm labor in 1961. It is possible that the shortages reported by farmers are genuine ones and mechanization is, in part, a response to this permanent labor scarcity. It was noted that permanent labor has traditionally been provided by specific social communities and the rural labor in general does not compete for permanent farm jobs. On the other hand, the author observed that wages for permanent

labor differed substantially between different areas. This would suggest that there may be no overall shortage and the real problem may be lack of mobility between different areas. Research on the availability of permanent labor is very significant because the case for bullock cultivation generally rests on the assumption that there is no shortage of labor for this purpose.

4. The recommendations for Pakistan regarding the auxiliary tractor equipment and the package of other inputs and practices are mainly based upon technical considerations aimed at maximizing the output per acre. The farmer's response, however, is mainly determined by the economic profitability of these inputs. As rational economic decision makers they tend to "optimize" rather than "maximize" the input use. It is very essential, therefore, that research should be done on the economics of (1) tractor equipment for deep plowing, row crop sowing, etc.; and (2) other improved inputs and practices such as the level and combination of fertilizers, hoeing, weeding, etc.

5. As discussed earlier, research towards shortening the growing season of cotton promises very high returns in terms of double cropping possibilities. Research efforts need to be concentrated on varietal

improvement in cotton to develop short season, disease-resistant varieties. Some success has already been achieved in developing a short season variety but its adoption by the farmers has been on a limited scale due to heavy pesticide requirements.

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APPENDICES

APPENDIX A

CASUAL LABOR USED PER ACRE OF DIFFERENT CROPS

APPENDIX A

CASUAL LABOR USED PER ACRE OF DIFFERENT CROPS

Table A.1 gives the details of the casual labor estimates shown in Chapter IV. The per acre labor used was derived on the basis of both structured and unstructured questions. Information on the amount of total labor (casual and permanent) used for the different crop operations was obtained by asking questions via the questionnaire. Different operations, however, varied in the casual component of the total labor used. Information on the crop operations using casual labor was obtained through informal discussions with a selected number of farmers in different areas. Local officials of the Department of Agriculture were also interviewed.

In general, the use of the casual labor will vary with the size of the holding. With an increase in the size of the holding, the use of casual labor tends to increase due to the family labor limitations and the higher level of income and the social status of the farm operator. Since this study deals with farms having an average size of around 45 acres, these results may differ from other studies dealing with different farm sizes.

According to the table, the use of the casual labor was concentrated on the harvest operations; it was only for

TABLE A.1.--The Casual Labor Used Per Acre of Different Crops on Bullock and Tractor Farms Surveyed in the Punjab.

Crop		Casual Labor Use Per Crop Operation In Man Hours Per Operation Per Crop							Total Man Hours Per Acre
		Sowing	Hoeing	Harvest Cutting	Threshing	Winnowing	Picking	Processing	
1. Wheat									
a. Rice Area -	Tractor			40.0		32.0			72.0
	Bullock			35.0		24.0			59.0
b. Other Areas -	Tractor			40.0		32.0			72.0
	Bullock			40.0		32.0			72.0
2. Toria				16.0		16.0			32.0
3. Gram						16.0			16.0
4. Tobacco		17.5	32.0	20.0				113.0	183.0
5. Rice									
a. Rice Area -	Tractor	21.0	2.0	26.0	26.0				75.0
	Bullock	26.0	2.0	35.0	35.0				98.0
b. Other Areas -	Tractor	20.0	-	16.0	16.0				52.0
	Bullock								
6. Cotton									
a. Cotton Area -	Tractor		7.0				134.0		141.0
	Bullock		4.0				160.0		164.0
b. Lyallpur -	Tractor		4.0				134.0		138.0
	Bullock		11.0				112.0		123.0
7. Maize -	Tractor		12.0					38.0	50.0
	Bullock		14.0					38.0	52.0
8. Sugarcane									
a. Lyllpur Area		48.0	29.0	120.0				150.0	347.0
b. Cotton Area		48.0	29.0	100.0				140.0	317.0
c. Rice Area		48.0	29.0	60.0				75.0	212.0
9. Vegetables (Musk Melons)			64.0				216.0		280.0

rice, sugarcane and tobacco that some casual labor was also used for the sowing operations. The pattern of the casual labor use indicated here is confirmed by a study by the World Bank in 1966 (30) and a more recent study by Eckert. According to Eckert, "of all the possible agricultural operations , farmers most often engage temporary labor for those associated with harvesting" (16, p. v-1).

Given the overall pattern of casual labor use, the underlying factors that determined the causal labor used per acre of different major crops are explained below.

Cotton: Cotton picking involves female labor. Five women working for an eight-hour day can pick an acre of fully mature cotton. The female members of the farm households under study, except the old lady, do not go out for the field work. The old lady or the eldest female member of the family does the supervision and also picking along with the four casual female workers. The number picking will vary depending on the yield.

Rice: Rice is the only major crop which uses casual labor for both the sowing and all of the harvest operations. As already mentioned, the rice sowing technology in the Punjab requires intensive land preparation, plowings, and plankings in the standing water. Moreover, most of the rice follows wheat and 100 per cent of the crop is transplanted. Under this situation the permanent labor force remains busy in preparing field after field, and most casual labor follows with the transplanting of the rice. The harvest operations are also performed by casual labor, while the permanent labor undertake the land preparation for wheat, most of which follows rice. Moreover, at the rice harvest as well as the sowing time, the permanently hired labor will either leave the farm work or will have to be paid the higher peak season wages.

Sugarcane: The sowing of the sugarcane is a short-term but very labor intensive operation. Specific labor teams are organized by bringing in a lot of casual labor for the sowing operation. The cutting and processing of the sugarcane, on the other hand, are performed over a period of three to four weeks per acre. This is why the family labor mostly handles these operations with casual labor accounting for about one-fourth of the total.

Vegetables: The vegetables, in general, were grown on very small area for the domestic consumption. The musk melon is a special vegetable--rather half fruit, half vegetable--which was grown on a substantial area by a small number of farmers. All post-sowing operations were performed by hired labor paid in the form of the share of the crop.

Toria and Gram: Their winnowing requires special skills and was generally performed by the casual labor. Toria cutting, which falls during the sugarcane harvest and processing peak, also engages about 50 per cent casual labor.

APPENDIX B

QUESTIONNAIRE

Farm Mechanization in Pakistan Punjab

Complete Before Interview...

District	
Tehsil	
Union Council	
Village	
Interviewer:	
Date:	

QUESTIONNAIRE

P_A_R_T -A

1. Name of the Farmer: ____________ Age: ______

   Education: ____________

2. Nearest Mandi/Town: Name ____________ Distance ______

3. Land owned in this Village ____________ Acres ______

4. Land owned in other villages/districts: ________ Acres

_P_A_R_T_-B

5. Total Area under own cultivation: ________ Acres

6. Cropping Pattern, Yields and Requirements of Labor and Bullock and tractor power(See next two pages)

7. Which crops preceded in the acreage planted with cotton, maize, rice and Kharif Fodder.

Kharif Crops 1971	Total Acreage	Acreage after Fallow	Acreage after other crops				
			Wheat	Fodder	Gram	Toria	Veg:
Cotton							
Maize							
Rice							
Kharif Fodder							

CROP OPERATIONS AND REQUIREMENTS OF

CROPS KHARIF-'7[illegible]	TOTAL ACRAGE	YIELD PER ACRE		PREPARATORY		LAND LEVELLING	SEED-BED & SOWING		FERTILIZER	
				PLOW	PLANK		PLOW	PLANK	FYM	CHEM.
1. RICE										
(a) COARSE			INT.	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
(b) BASMATI			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
(c) IRRI			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
2. MAIZE										
(a) DESI			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
(b) HYBRID			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
3. COTTON			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
4. FODDER			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
5. TOBACCO			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
6. SUM. VEG. MUNG			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-

LABOR(L), BULLOCK PAIR(B) AND TRACTOR(T) POWER.

BUND MAKING	WATER COURSES	HOEING WEEDING	SPRAYING	THINNING	TRANSPLANT	IRRIGATION R+O	CUTTING PICKING	THRASHING	DECOBI. DRYING SHELLING	STALK REMOVING	RICE NURSERY LAND PREP	RICE NURSERY FYM	RICE NURSERY SPRAY
A	A	A	A	-	A	N	-	-	-	-	A	A	A
MD	MD	MD	MD	-	MD	-	MD	MD	-	-	MD	MD	MD
-	-	-	-	-	-	-	-	-	-	-	A	BD	-
-	-	-	-	-	-	-	-	-	-	-	A	TH	-
A	A	A	A	-	A	N	-	-	-	-	A	A	A
MD	MD	MD	MD	-	MD	-	MD	MD	-	-	MD	MD	MD
-	-	-	-	-	-	-	-	-	-	-	A	BD	-
-	-	-	-	-	-	-	-	-	-	-	A	TH	-
A	A	A	A	-	A	N	-	-	-	-	A	A	A
MD	MD	MD	MD	-	MD	-	MD	MD	-	-	MD	MD	MD
-	-	-	-	-	-	-	-	-	-	-	A	BD	-
-	-	-	-	-	-	-	-	-	-	-	A	TH	-
A	A	A	A	-	-	N	-	-	-	-	-	-	-
MD	MD	MD	MD	-	-	-	MD	-	MD	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
A	A	A	A	-	-	N	-	-	-	-	-	-	-
MD	MD	MD	MD	-	-	-	MD	-	MD	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
A	A	A	A	A	-	N	-	-	-	-	-	-	-
MD	MD	MD	MD	MD	-	-	MD	-	-	MD	-	-	-
-	-	-	-	BD	-	-	-	-	-	-	-	-	-
-	-	-	-	TH	-	-	-	-	-	-	-	-	-
A	A	A	A	-	-	N	-	-	-	-	-	-	-
MD	MD	MD	MD	-	-	-	MD	MD	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
A	A	A	A	-	A	N	-	-	-	-	-	-	-
MD	MD	MD	MD	MD	MD	-	MD	MD	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
A	A	A	A	-	-	N	-	-	-	-	-	-	-
MD	MD	MD	MD	-	-	-	MD	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-

REFERENCE:

INT. = INTENSITY
L = LABOR
BD = BULLOCK-PAIR DAY
T = TRACTOR
A = ACRE
MD = MAN DAY
TH = TRACTOR HOUR
A/B = ACRE/BAG
N = NUMBER
R+O = RAUNI + OTHERS
P = PERMANENT LABOR
C = CASUAL LABOR.
B = BULLOCK-PAIR.
NOTE: L = P+C

CROP OPERATIONS AND REQUIREMENTS OF LABOR,

CROPS RABI 1970-71	TOTAL ACRAGE	YIELD PER ACRE		PREPARATORY PLOW	PREPARATORY PLANK	LAND LEVELING	SEED-BED & SOWING PLOW	SEED-BED & SOWING PLANK	FERTILIZER FYM	FERTILIZER CHEM.
1 WHEAT: (a) DESI			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
(b) MEXI-PAK			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
2. BERSEEM			INT	A	A	A	-	-	A	A/B
			L	MD	MD	MD	-	-	MD	-
			B	A	A	BD	-	-	BD	-
			T	A	A	TH	-	-	TH	-
3. GRAM			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
4 TORIA			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
5 TURNIPS			INT	A	A	A	-	-	A	A/B
			L	MD	MD	MD	-	-	MD	-
			B	A	A	BD	-	-	BD	-
			T	A	A	TH	-	-	TH	-
6 SUGARCANE			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-
7 WIN. VEG.			INT	A	A	A	A	A	A	A/B
			L	MD	MD	MD	MD	MD	MD	-
			B	A	A	BD	A	A	BD	-
			T	A	A	TH	A	A	TH	-

BULLOCK PAIR AND TRACTOR POWER

BUND MAKING	WATER COURSES	HOEING/ WEEDING	SPRAY-ING	EARTHING UP	IRRIGATION R+O	HARVEST-ING	THRESH-ING	WINNOW-ING	GUR MAKING
A/MD	A/MD	A/MD	A/MD	-	N	MD	MD/BD/TH	MD	-
A/BD	A/BD	A/MD	A/MD	-	N	MD	MD/BD/TH	MD	-
A/MD	A/MD	-	A/MD	-	N	MD	-	-	-
A/MD	A/MD	A/MD	A/MD	-	N	MD	MD/BD/TH	MD	-
A/MD	A/MD	-	A/MD	-	N	MD	MD/BD/TH	MD	-
A/MD	A/MD	A/MD	A/MD	-	N	MD	-	-	-
A/MD	A/MD	A/MD	A/MD	A/MD	N	A/MD/BD/TH	-	-	A/MD/BD/TH
A/MD	A/MD	A/MD	A/MD	A/MD	N	MD	-	-	-

REFERENCE:

INT. = INTENSITY
L = LABOR
BD = BULLOCK-PAIR DAY
T = TRACTOR
A = ACRE
MD = MAN DAY
TH = TRACTOR HOUR
A/B = ACRE/BAG
N = NUMBER
R+O = RAUNI + OTHERS
P = PERMANENT LABOR
C = CASUAL LABOR
B = BULLOCK-PAIR

NOTE: L = P + C

6 (a) Method of Sowing:

Crops	Broadcast (Acres)	TRANSPLANT /Hand pore (Acres)	Seed drill (Acres)	Seed-Cum-Fertilizer drill (Acres)
1. Wheat				
(a) Desi				
(b) Mexi Pak				
2. Rice				
(a) Course			—	—
(b) Basmati			—	—
(c) Irri			—	—
3. Cotton				
4. Maize				
(a) Desi				
(b) Hybrid				
5. Gram.				

8. Which crops preceded in the acreage planted with Wheat Gram, Toria and Fodder during Rabi 1970-71?

Rabi 1970-71 Crops	Total Acreage	Acreage after fallow	Acreage after other crops: Rice	Maize	Cotton	Fodder
Wheat						
Rabi Fodder						
Gram						
Toria						

9. Livestock and poultry enterprises:-

Kind of livestock/ Poultry.	Starting Year.	Present Number	Number in Milk	Employment (Man years) starting Year	At present
Buffalo					
Cow					
Sheep					
Goat					
Other livestock					
Poultry					

10. Have you introduced new crops or left the cultivation of old crops during the last five years. Yes ☐ No. ☐

If yes, crops: Introduced: 1________ 2________ 3________

Left 1________ 2________ 3________

PART-C

Notes:- B: Before the tractor use
N: Now
Only 'N' Column applies to Non users of Tractor.

11. Family male Labor

	Relationship to the Head	Age	Education	Working On Farm Full-time B	N	Part-time B	N	Off-Farm Full-time B	N	P-time B	N
A-Adults(10-50)											
1											
2											
3											
4											
5											
6											
7											
8											
B-Others(less than 10 and greater than 50)											
1											
2											
3											
4											

12. Number of permanent Hired Labor:

	Male	Female	Total
a) In the year preceding the tractor use	____	____	____
B) At present	____	____	____

13. Availability of Family and permanent hired labor(in man days) during the peak demand months

Labor Type	MONTHS April(30)	May (31)	June(30)	September(30)	Oct.(31)	Nov(30)
			DAYS			
1. Family labor						
a) Operator						
b) Other Male						
i)						
ii)						
iii)						
iv)						
v)						
vi)						
vii)						

2. Hired Permanent:					
i)					
ii)					
iii)					
iv)					

14. Wages Paid

	NOW				BEFORE			
a) Permanent labor wage per month/ Year.	Cash (Rs)		Kind 1 2 3 4		Cash (Rs)		kind 1 2 3 4	
b) Casual labor wage per hour/ day	Apr-June & Sept-Nov		Other Months		Apr-June & Sept-Nov		Other Months	
	Cash (Rs)	Kind 1 2 3 4	Cash (Rs)	Kind 1 2 3 4	Cash (Rs)	Kind 1 2 3 4	Cash (Rs)	Kind 1 2 3 4

15. Labor Availabiltiy:

a) Is additional permanent labor available?

i) Available at the going wage rate

Easily ☐

With difficulty ☐ If so the kind of difficulty-----------

---

ii) Available at higher wage rate

Easily ☐

With difficulty ☐ If so the kind of difficulty---------

---

iii) Reasons for the shortage:-----------

Contd......

b) Is additional casual labor available?

i) Available at the going wage rate [ ]

ii) Available at a higher wage rate [ ]

iii) Not available [ ]

iv) Reasons for the shortage if any: ______

c) Does labor migeration from other areas take place during the following months?

Yes [ ] No [ ]

If yes:-

i) From which area/District ______

ii) What percentage migerants are of the local casual labor?

MONTHS	PERCENTAGE
April	______
May	______
June	______
September	______
October	______
November	______

Comments of the Interviewer: ______

______

______

P_A_R_T -B

16. (a) Do you own bullocks? Yes [ ] No [ ]

If yes, the pairs of working bullocks ______

(b) Bullock drawn Implements:

1. Desi Plough
2. Pakistan Plough/Mould board plough
3. Meston Plough
4. Raja Plough
5. Disc Harrow
6. Spike tooth Harrow
7. Seed drill
8. Seed-cum-fertilizer drill

Contd....

17. Do you use a tractor? Yes /__/ If so continue with Q.No.18.
No /__/ If no, go to part F.

18. Do you own a tractor? Yes /__/ If so continue with Q.No.19.
No /__/ If no,go to part E.

19. How many tractors do you own? ___________

20. Tractors

Tractors	1	2	3
Year of Purchase	____	____	______
Horse-power	____	____	______
Price paid	____	____	______

21. Reasons for the purchase of the tractor:-

(a)

(b)

(c)

(d)

22. Have the total production and yield per acre increased on your Farm after the purchase of the tractor,

Yes /__/ No /__/

If Yes, the reasons for the increase in

a) Total production:- 1 2
3 4

b) Yield per acre:- 1 2
3 4

23. Tractor drawn implements and equipment:

	Number	Year of Purchase
a) Disc Plow	______	________
b) Mouldboard Plow	______	________
c) Cultivator	______	________
d) Disc Harrow	______	________
e) Steel Planker	______	________
f) Rabi/Seed-Cum-Fertilizer drill	______	________
g) Kharif Drill	______	________
h) Row Crop Planter	______	________

i) Tractor Powered Sprayer ________ ____________

j) Farm Wagon ________ ____________

k) Trailer ________ ____________

24. Uses of the Tractor Engine:

(a) Thresher Yes ☐ No ☐

(b) Cane Crusher Yes ☐ No ☐

(c) Fodder Cutter Yes ☐ No ☐

(d) Others Yes ☐ No ☐

25. Do you hire out the tractor? Yes ☐ If so, continue with No.26.

No ☐

26. Purpose for which tractor hired out at present and price received.

NOTE:- A= Acres; p= price in Rs.

a) Hiring Out for Farm Activities.

Operation		Wheat	Borseem	Rice	Maize	Cotton	Sugar-cane	Veg S	Veg W	S.Fodder
1. Plow & Planking	A									
	P									
2. FYM	A									
	P									
3. Threshing	Hours/Mds									
	P									
4. Transportation:										
a) Inputs	Mds									
	P									
b) Products	Mds									
	P									

b) Hiring Out for Non-Farm Activities
Note:- T= Time in Hours; I = Income received in Rs.

		MONTHS											
		J	F	M	A	M	J	J	A	S	O	N	D
Non-Farm Haulage.	T												
	I												

27. Have you installed a tubewell: Yes ☐ No ☐

If yes,

a) The year of Installation: ______________

b) Capacity: ______________.

P_A_R_T - E

28. When was the tractor hiring started? Year__________

29. a) Hiring for Farm Activities

Purpose for which tractor hired at present and the price paid.

A= Acres

P= Price in Rs.

Operations		Wheat	Berseem	Rice	Maise	Cotton	Sugar-cane	Veg S	Veg W	Summer-Fodder.
1. Plow & Planking	A									
	P									
2. FYM	A									
	P									
3. Thresh-ing	Hour/Mds									
	P									
4. Transpor-tation										
a) Inputs	Mds									
	P									
b) Products.	Mds									
	P									

b) Hiring for Non-Farm Activities
(T=Time in Hours; I= Income received in Rs.

	J	F	M	A	M	J	J	A	S	O	N	D
T												
I												

P_A_R_T- F

30. Do you use a thresher? Yes ☐ No ☐ If so, continue with No.31.

31. Do you own the thresher? Yes ☐ If so, continue with No.32
No ☐ If so, go to No.36

32. Year of purchase ______________

Price paid Rs. ______________

Contd.....

33. Crops for which thresher used:-

a) Wheat ____________

b) Toria ____________

c) ____________

34. Do you hire out thresher? Yes [ ] No [ ] If so, continue with No.35

35. Purpose for which thresher hired out and the price received.

Crops	Time/Hours	Price per Hour/Mds
a) Wheat		
b) Toria		
c)		

36. When was the thresher hiring started? Year____________

37. Purpose for which the thresher hired and the price paid.

	Crops	Time/Hours	Price per hour/Mds Rs
(a)	Wheat		
(b)	Toria		
(c)			

P_A_R_T-G

38. Size of the Farm:

(a) Land Owned: ____________Acres

(i) Land Inherited: Total ____________Acres

Year ____________Acres

Year ____________Acres

Year ____________Acres

(ii) Land Purchased: Total_____Acres

Year ________ ____________Acres

Year ____________ ______________Acres

Year ____________ ______________Acres

(b) Land rented in: Year 1971 __________Acres

(•) Land Rented out in Year 1971 __________Acres

39. Comments of Interviewers on Seller and Renter of Land:

(a) What did he do with the sale/Rent money?

(i) Seller __________________________

(ii) Renter __________________________

(b) His total land area after selling/Renting?

(i) Seller ________________

(ii) Renter ________________

(c) Reasons for selling/Renting

(i) Seller _______________________

(ii) Renter _______________________

40. Land under cultivation

	Year	Own Cultivation (Acres)	Tenants (Acres)	Number	Terms Cash	Kind
Tube-well Installation.						
Tractor purchase						
Now	1971					

PART- H

41. Processing Activity:

Kind of Activity	Starting Year	Total Investment	Employment
Flour Mill			
Rice Husking Mill			
Fruit Processing			
Milk Processing			
Poultry Processing			
Vegetable Processing			
Wool & Cotton Processing			
Saw Mill			
Brick Kiln			
Coal Making			
Rope Making			
Bee Keeping			
Sericulture			
Other			

42. Non-Farm Investments:-

Type of Enterprise	Year of Investment	Amount of Investment Rs.
Commerce		
Transportation		
Industry		

43. Future Plans:

(a) Buying more land? Yes /__/ No /__/

If yes, how much? ____________acres

(b) Renting more land? Yes /__/ No /__/

If yes, how much? ____________acres

(c) Buying tractor/implements and increasing the use of the tractor?

Yes /__/ No /__/

(d) Increasing tractor hiring? Yes /__/ No /__/

(e) Increasing livestock and Poultry? Yes /__/ No /__/.

(f) Increasing fruits and vegetables? Yes /__/ No /__/

(g) Increasing processing activity? Yes /__/ No /__/

(h) Increasing non-farm investments? Yes /__/ No /__/

If yes, in which enterprises? ________________________

APPENDIX C

TABLES ON NET FARM REVENUE ON TRACTOR AND BULLOCK FARMS

TABLE A.2.--Net Farm Revenue on a Tractor and a Bullock Farm in the Tubewell and Non-Tubewell Areas. (Market Prices 1970-71)

Size of Farm (Acres)	Net Farm Revenue (Rs.)			
	With Tubewell		Without Tubewell	
	Tractor	Bullocks	Tractor	Bullocks
25	20,894	10,548	10,598	8,403
50	30,928	18,473	18,293	14,531
75	36,060	26,112	26,053	21,796

TABLE A.3.--Net Farm Revenue With Tubewell Under Different Forms of Mechanization Compared to Bullock Cultivation.

Size of Farm (Acres)	Net Farm Revenue (Rs.)			
	Tractor Only	Tractor + Bullocks	Tractor + Thresher	Bullocks Only
25	20,894	18,370	21,398	10,548
50	30,928	33,371	38,360	18,473
75	36,060	42,305	45,015	26,112

TABLE A.4.--Net Farm Revenue on a Tractor and a Bullock Farm in the Tubewell and Non-Tubewell Area. (World Market Prices)

Size of Farm (Acres)	Net Farm Revenue (Rs.)			
	With Tubewell		Without Tubewell	
	Tractor	Bullocks	Tractor	Bullocks
50	45,870	29,374	23,221	18,859

TABLE A.5.--Net Farm Revenue on a 50-Acre Tractor Farm and a 50-Acre Bullock Farm at Different Levels of Maximum Restrictions on the Tubewell Water Pumping.

Permissible Maximum Tubewell Water Pumping (Acres Inches Per Annum)	Net Farm Revenue (Rs.)	
	Tractor Farm	Bullock Farm
5760[a] (418)[b]	30,928	18,473
400.0	30,914	18,473
200.0	28,801	18,099
100.0	25,759	16,448
50.0	22,937	15,506
25.0	20,917	15,033
12.5	19,688	14,786
000.0	18,291	14,531

[a]Maximum permissible.

[b]Actual utilization.

APPENDIX D

EXPLANATION OF INDIGENOUS TERMS

APPENDIX D

EXPLANATION OF INDIGENOUS TERMS

1. Rupee: The local standard currency. The term Rs. used in the text means rupees.

2. Maund: The standard unit of measure. One maund = 82.28 pounds.

3. Rauni: The field irrigation meant to facilitate the seed-bed preparation.

4. Gur: Raw native brown sugar prepared from sugarcane juice. Gur is roughly one-tenth of the sugarcane.

5. Paddy: Unhusked rice. Cleaned rice is about two-thirds of paddy.

6. Rabi: Winter crops growing season.

7. Kharif: Summer crops growing season.