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CONVENTIONAL ENERGY AS A CONSTRAINT TO THE GREEN REVOLUTION 196.-1984: THE PUNJAB CASE

PN-AAR-862

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April 15, 1969

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CHAPTER - 1

INTRODUCTION

a) Objective, Scope and Purpose of the Exercise

This paper is an attempt to provide some guidelines for policy decisions in the area of the mechanisation of farm activities in Punjab. This is a subject which is at once most sensitive (on a number of counts; especially labor displacement) and is at the same time not as well understood at the aggregate level as at the farmer level. A great many analyses have been produced which demonstrate quite conclusively the benefit to the individual farmer which would follow from the mechanization of parts of his operation. The usual rebuttal is that the costs to society are overlooked in this type of micro-analysis and that they are likely to be considerable, due to the social costs involved with the displacement of agricultural laborers having a very low or zero opportunity cost relative to their present occupation. On the other hand, there are social benefits which would occur from the production of cheaper, and larger quantities of agricultural products. A cost must be debited to society if it fails to take advantage of an opportunity to produce more cheaply.

These economic considerations are beyond the scope of this paper but can be influenced by its findings.

Generally, the work seeks to identify whether, and under what circumstances, conventional energy supplies (human and animal), acting through the technology presently in use in Punjab, will become a

constraint to cropping postulated acreages of crops. If conventional inputs are a constraint an economic justification can be made at the macro-level to supplementing these inputs with a new technology which may, to some degree, displace the demand for the conventional input. A number of technical alternatives are becoming feasible to Punjab Farmers: The energization of pumping activities is one, mechanical threshing is another. The introduction of shorter duration higher yielding input sensitive varieties is a third. Finally, capital intensive machinery - combines and tractors - are coming into the scene; the latter rather rapidly.

A complete analysis of the alternatives and opportunities; costs and benefits are beyond this work. Its specific objectives are nonetheless ambitious considering the amount of data which has to be collected, and manipulated. They are:

i) to estimate the magnitude and pattern of conventional energy use on Punjab farms, monthly, over selected crop years: 1964-65, 1968-69, 1973-74, 1978-79 and 1983-84.

ii) to account for this pattern as a function of crop rotation and acreages under different crops as well as the energy needs of these crops under the traditional technology.

iii) to inquire into the effects on production of this pattern, if demand for energy exceeds available supply through the impact of the shortfall on timeliness of operations.

iv) to test the effect on the demand for energy as a result of incremental changes in farm technology: pumpsets, HYV, threshers. And from this, remark upon the consequent opportunities to increase yield through improved timeliness, multiple cropping etc.

v) to estimate the trade-off between the new input and the conventional one formerly used to perform a given task.

From these specific objectives it is hoped that more general insights can be developed (elsewhere if not herein) regarding:

i) the pattern of farm labor use in Punjab and pattern of its development as a result of changing technology.

ii) the composition of labor which be displaced whose needs would consequently have to be recognized as a result of the technical change.

iii) the benefits which would follow from a change in rural technology.

iv) the associated costs.

v) the general guidelines as to public policy in this area.

b) The Setting

This study, and its conclusions, are limited to the former Punjab (now partitioned into Punjab and Haryana). The antecedent state was kept as a basis for analysis because of the existence of a broad statistical base made for the erstwhile Punjab from which we developed our projections. Punjab was selected as the studied state for reasons both practical and potential. Practically, Punjab has the best farm management data in India collected over a period of a third of a century. Potentially, the state is the one with the greatest liklihood of early mechanization on a large-scale. It is already an advanced state, and every indication points to the Punjab remaining as a pace-setter in rural development. Unfortunately, for some of the many reasons which make the outlook as hopeful, generalization to India as a whole from the Punjab experience must be done very cautiously and with qualification.

Punjab is in many ways the extreme (in the positive sense) case in Indian agriculture. Many of the conclusions reached in this study are relevant to it alone or of more limited relevance to north-west India. The reason for this polarity stems from the reversal of many norms for Indian agriculture as to comparative: size of farm, conditions of tenancy, owner-operation of farms, levels of education and use of new technology. What is true for this area is not necessarily true for the rest of India and vice versa.

Punjab is one of the smaller Indian states, whose arable lands are in large part centered in irrigable or rain-assured areas. At present more than 50% of the arable land is irrigated (2/3 by canal, 1/3 by well) and there is great scope for both increasing the total irrigated area and increasing the intensification of irrigation. Well endowed with sub-soil water sources, good use is now beginning to be made of this resource as energized tube wells become available.

In 1968 the state had an average cropping intensity of 130% (versus 114% for India). It is expected that this figure will rise to 160% in another fifteen years.

Punjab is known as a wheat producing area, which crop accounts for nearly a quarter of the cropped area. Hence, the state has been one especially fortunate in having its principal food crop most affected by the HYV program. Foodgrains, as a whole, consitute nearly three-quarters of the gross cropped area including millets, rice, maize and pulses. Cane and cotton are the principal cash crops.

Unlike India as a whole, Punjab is a land of large (by Indian standards), owner-operated farms. Sixty per cent of the cultivating households operate farms larger than 7.5 acres compared to 28% for the all-India average, and 80% of the Punjab farms do not exceed 10 acres. Only 12% of Punjab farms are smaller than 2.5 acres whereas the all-India figure is nearly 35%. As a result the representative farm in the state is a "one-pair" holding (i.e., is large enough to support a pair of bullocks) on water-assured land. Most farms are owner-operated, but the tenure relationship usually followed in the state has the owner contribute to the purchase of costly inputs and the tenant profit from the final extra output.

Farms in Punjab are mainly consolidated.

The state has a below average endowment of draft-animals (the number of animals per hundred acres being 13.6 compared with the all-India figure of 24). But their size and capacity for farm work is much above the average. About 16% of the gross cropped area is under fodder crops to support them and the other animals.

Rural electrification is making rapid progress and is having its impact on the rapid acceptance of energized tube-wells.

Unlike India as a whole, Punjab as a comparatively small landless labor force, only 10% of the total rural labor supply. Moreover, this group appears to be a declining one, notwithstanding the considerable wages paid during the two peak work periods. Off-farm opportunities seem to be attracting increasing numbers of people, which will work to reduce the rural labor force yet further.

Punjab as a whole has been a leader in acceptance and level of use of pumpsets, mechanical threshers, tractors, fertilizers, pesticides and new seeds. It seems to have an effective cooperative system, unlike many other areas. The state has been a persistent 'surplus' area throughout the droughts of the mid-sixties. In addition to these technical characteristics it is worth commenting that Punjab appears to have been making a more sustained attempt towards improving its farm sector for a longer period than almost any other region of India. This effort has been accompanied by good farm management data collection which is of immense benefit both to students and to state planners. Without this data, unusual in India both as to the period available and its detail, an analysis of energy needs in the state could not be performed.

For all these reasons Punjab is different, and for these reasons will likely require a farm policy especially adjusted to its needs if its potential is to be realized.

c) Methodology

An essentially budgetary technique is used based upon the projection of relevant variables over the studied period (1968-69 to 1983-84). The supply of energy from conventional inputs will be projected from their known populations supplemented by a compound growth rate. From these projections will come an estimate of the stock of energy (from man or animal) available to farmers in a given year. Against this stock the relevant monthly demand for energy from all crops will be cast to allow us to ascertain in which months, and for what reasons, the pattern of demand is what it is.

Estimating the demand for energy will be somewhat more complicated. First, the monthly demand for energy for the production of each crop must

be made (from each energy input). Second, the number of acres under each crop must be estimated, over the studied period. Third, the per acre demand for energy per crop must be combined with the number of acres and then summed across all crops in a given studied year.

In the first phase of our study, the emphasis will be upon the present crop pattern (which determines the pattern of energy use) and upon the present technology. Subsequently, alternative technologies will be examined. Each will involve some displacment of the demand for energy from the conventional source, and this substitution will be reflected in the shift in demand (usually a decline) associated with the substitution of the new energy input or technology.

Projections of the secular rate at which such changes will occur have been made, and this rate of displacement of conventional inputs, and our assumption in this regard can be challanged:

Much of the discussion as to the effect of these changes in technology on yield are based on conjecture, but some experimentations data is introduced to give an indication of the effect of timeliness of activity upon yield.

Finally, it should be noted, that our data on the energy requirements came in rather crude form, not being originally intended for the use we made of it. Consequently, these general activities are specified: Plowing-sowing; Inter-culture; Irrigation and Harvest; Threshing. Where these had to be further refined, judgement had to supercede specific evidence.

CHAPTER 2

Pattern of Energy Use on Punjab Farms

Before plunging into the analysis it will be worthwhile to consider the present pattern of energy use on Punjab farms as the subsequent chapters will involve themselves in variations from this basic pattern due to changes in technology and cropping patterns. This chapter will restrict itself solely to a consideration of the factors affecting and accounting for the pattern of energy for the present technology employed on Punjab Farms.

The demand by a farmer for energy is a function of: (1) the crop raised; (2) the type of soil; (3) level of rainfall; (4) intensity of cropping; (5) the crop rotation followed and (6) the technology used.

Muscle, human and animal, provides the basic energy utilized on Punjab farms. Theoretically the source of energy is of no consequence to farm operations so long as the job is performed at the proper time. Man can plow, sow, irrigate, harvest and thresh a crop unaided. Practically speaking, however, the availability of non-human energy is of immense benefit in carrying out farm operations. A pair of bullocks is both cheaper and more efficient than gangs of men. Moreover, sufficient labor to perform farm operations is unavailable at peak periods even in 'labor-rich' India. Draft animals are the principal source of non-human energy on farms; and the production of a crop involves a technology which makes use of man and bullock as complementary inputs for all farm activities.

The pattern of application of energy is dependent upon the characteristics of the crops, used in a farm rotation. The pattern of energy use for the state as a whole is, therefore, the sum of that required by these rotations and for this reason it is useful to have understanding of these rotations, their crops, and their specific energy needs. Two types of rotation will be considered: those on irrigated and on unirrigated land. The typical crops grown are wheat, cotton, millets, cane, pulses, and rice, which figure in the most important rotations. Potatoes, and similar garden crops, are becoming important but (as these are grown mainly around the cities, on a very small proportion of the total cropped area), they will be largely excluded.

A given crop is typically specific to a certain time of year, for reasons involved with the physiology of the plant itself. Plant breeders can and do influence this basic chemistry, but usually concentrate on shortening duration and increasing yield rather than fundamentally altering the seasonality of the plant. A farmer has, therefore, in a particular season, only a certain group of plants which it is feasible to grow and for reasons of duration, the decision as to one crop may affect successive crops as well.

If its yield is to be optimal, a crop must be planted at a certain time; its seed bed must have a certain quality of preparation (which affects germination); a certain level of irrigation must be provided and certain cultural practices performed. A plant will ripen within a known time period; on or about a certain data as a result of the inter-

action of heat and light. Consequently, if a crop is sown late it will ripen on time but produce a smaller yield. The harvest must be gathered within a reasonable time as well; to minimize losses from shatter, pests, weather and predators and, moreover, to make way for the following crop.

A typical crop rotation for unirrigated areas would involve a millet or a kharif pulse crop planted in July and harvested in October-November. This crop would utilize most of the rainfall moisture in the soil.

With the provision of irrigation water more varied crop rotations become feasible. The most important rotation in Punjab and the most flexible, (in that the duration of any single crop, except sugarcane, is no more than six months) has a maize crop planted in June-July and harvested in October-November. This is followed by wheat in November which is harvested in April. In May and June a short fallow can be allowed prior to the next maize crop, or a short-term pulse can be put in. A likely alternative is to plant a cotton crop in April-May which can be brought in by November and followed by wheat. Rice, too, can be substituted for cotton in the summer rotation.

Alternatively a more rigid rotation can be adopted using cane, which has a year duration. In this instance, the July maize crop is followed by either clover or potato which is harvested in February. Cane is planted in February-March. Cane requires continuous attention,

although not of sufficient magnitude to much affect total energy demand peaks for Punjab. The crop is ready for cutting by November. If the sugar mills delay cane receipts, it may remain standing until April. A grave loss to the farmer - and a possibility to ponder carefully before planting the crop. Once the cane is cut it can either be ratooned for another year or be followed by pulse, rice or maize and these in turn by wheat in November.

A third type of rotation, most often found near cities, has the summer maize crop followed by two consective crops of potatoes. This rotation can be varied to include a number of vegetables. Proportionately, this rotation is followed by only a minority of farmers in that this high value crop finds its market almost entirely in the cities, and requires a level of water and cultural management still beyond many farmers.

Timeliness, and intensity of operation, all of which require energy are essential ingredients to successful crop year. Shortages of energy at any time will cause tardy or inadequate performance of activities, which are directly associated with a decline in farm product. Hence, shortages of energy supply are more than a nuisance; they represent losses to both farmer and society.

Each crop has a unique pattern of energy need reflecting its cultural requirements and characteristics. (Table 2-1). These separate demands, when summed across all the crop rotations constitute the total pattern of energy demand. As wheat is the most important single crop

grown in Punjab its needs strongly influence the total pattern of the energy use. (Table 2-2). As a result, there are two peak demand periods for labor: October November and April-May. These peaks are separated by deep troughs.

A crop year (which begins in July - Kharif) sees a small peak, demand for labor when maize, rice, millets and pulses are planted on irrigated land and on unirrigated areas. Groundnuts are planted at this time also. After this activity, demand for energy substitutes or human labor is required only for the inter-culture of standing crops.

By late September the summer crop begins to mature and from there, until the end of November, the demand for all energy reaches its peak. Harvest activities claim most of the human labor. In November, much of the activity is involved with the tillage and planting of wheat. On unirrigated land, wheat preparation begins in September and peaks in October. From December until late March, demand for energy falls to its lowest in a crop year (although cane is planted and harvested in this period) and only picks up again in April when wheat is ready for harvest. At this time cotton is planted which is also very demanding of labor. June and July are devoted, once again, to maize, millets and other Kharif planting. The land is then fallowed through the summer to collect the moisture needed to support the succeeding autumn wheat crop. Wheat is harvested in April and is often followed by a millet crop once again in July.

Table 2-1

Monthly demand in man days of Energy, per ha. for Wheat

	Total Annual Demand	September	October	November	December	January	February	March	April	May
Irrigated	72.6	2.0	8.3	1.3	5.0	9.8	3.3	3.3	12.3	15.3
Unirrigated	51.1	9.0	10.2	2.1	2.5	-	-	-	12.3	15.0

Monthly Demand in Bullock Days of Energy, per ha. of wheat

Irrigated	31.3	7	5.0	9.7	4.0	1.7	1.7	1.6	1.0	5.9
Unirrigated	22.1	6.2	9.0	-	-	-	-	-	1.9	5.0

Calculated by authors from Farm Management Records.

Table 2-2 (a)

Man days required to prepare Selected Operations for Major Crops in Punjab per hectare (on irrigated unless otherwise noted)

Crop	Preparation & Sowing	Intercultura	Irrigation	Harvest/Threshing	
Wheat	22	7	16	28	[illegible]
Am. Cotton	15	16	15	42	[illegible]
Maize	18	21	14	25	[illegible]
Rice	34	12	8	18	[illegible]
Cane	30	34	70	120	[illegible]
Gram - irrigated	10	2	-	13	
- unirrigated	11	1	-	14	
Millets - unirrigated	8	3	-	15	[illegible]

Table 2-2 (b)

Bullock days required to prepare Selected Operations for Major Crops in Punjab per hectare

Wheat	17	-	8	6
Am. Cotton	11	4	4	-
Maize	12	3	7	-
Rice	14	1	2	1
Cane	15	4	32	33
Gram - irrigated	7	-	-	3
- unirrigated	7	-	-	3
Millets - unirrigated	6	-	-	2

Calculated by authors from Farm Management data.

The demand for bullocks has three unequal peak periods over the crop year. The greatest need is during the October-November period when animal energy is required for a last pre harvest irrigation of kharif crops, and for seed bed preparation of the rabi crop. A second peak comes in April-May when the kharif crop seed bed is prepared. The final peak is in July reflecting monsoon plowing, especially on unirrigated land, when plowing is used to retain moisture needed for the rabi crop. It typically takes a pair of bullocks about five days to prepare an acre for sowing (13 days for a hectare); three to four plowings and one sowing. Hence, a farm of five acres (about two hectares) will require nearly a month. This month input is not concentrated in one time but is allocated over a period, depending upon the alternative demands on the energy sources and rainfall.

If a farmer operates on rain-fed land he must prepare his land in such a way as to conserve the maximum moisture in it, and design his crop rotation in such a way as to make maximum use of the available moisture consistent with the energy available to him. Almost all of the moisture will come during the two month monsoon season (July-August). The farmer must plow his land before the rains start and then after each rain to hold this moisture for the fall crop. Thus, on rain-fed land, seed-bed preparation must begin in summer for the rabi season.

In the case of wheat the greatest need is during the planting period in October and November. Three to five plowings are required and at least one irrigation (if a well or canal is available). Once planted,

wheat requires little attention except for inter-culture, and irrigation until April, when it is harvested. Threshing will continue into May. (Table 2-2).

Farming irrigated land requires more energy than unirrigated. The extra effort to support irrigation operations is one reason. The fact that crops are larger on irrigated lands thus necessitating more labor in gathering them, is another. Finally as the rate of return to investment on irrigated lands is high (and as many farms have both types of land) the farmer will largely concentrate his efforts to his water-assured land. As a result, it takes about 73 man days to produce a hectare of wheat on irrigated land as opposed to 51 on unirrigated. A team of bullocks will be required for 31 days per hectare on irrigated land versus 21 days on the other. An irrigated hectare of wheat will require about 20 man days to till and two to sow; seven days will be spent on inter-culture; 16 for irrigation and 28 to harvest and thresh.

Irrigation requires labor as well. In the case of wells, labor is used to work the Persian wheel or Charsa (which functions only on some 10% of Punjab wells), tend the channels and bunds, and utilize water in fields (cropped or uncropped). For most crops, (cane again a major exception), pumping is the second most animal-intensive operation.

In most instances harvesting and threshing is the most labor-intensive and difficult operation. Nearly 50% of the labor used in cotton and cane cultivation is concentrated in bringing in the crop (and in converting the cane into raw sugar). Only rice, among the important food crops,

requires proportionately more of its labor input for preparation of land and planting (46%). The situation is almost exactly the reverse in the case of draft animals, except for cane which is very bulky and requires much energy to move the cuttings out of the field and crushing them.

With the information presented in this chapter we can now prepare a monthly estimation of the land for conventional energy, which will be done in chapter 4.

CHAPTER 3

THE SUPPLY OF ENERGY

a) The Human Input

In order to make an estimate of the stock of energy which will be available to farmers (over the study period) a number of projections must be made.

The basic data relating to the farm labor force in Punjab may be found in the two censuses (1951 and 1961), which give the figures for cultivators, (owner-operators and their families) and agricultural laborers. The proportion of the total population engaged in agriculture, as reported in these censuses is seen to be declining and the composition of the work force changing. For this reason, the first step toward making a projection of the supply of labor energy must be to project total state population growth. In doing this, it will be assumed that the family planning program will have no measurable effect on growth over the period. In any case, no persons born after 1970 will be entering the labor force as adults so that shifts in birth rates will only affect the labor force directly insofar as children are utilized. There is, moreover, reason to believe that children will become a progressively smaller portion of the labor force during the coming three plan periods.

The Expert Committee constituted by the Planning Commission in 1964 has made population projections for different states from 1961 to 1981, taking into account the likely impact of voluntary limitations on fertility (the effect of which so far has been trivial)[1/]. These projections, together with the total population of Punjab reported in the past two censuses, have been used to determine an average compound growth rate with which an interpolation of the total population for the years under study has been made. (Table 3-1).

Table 3-1

Population "Projections" for Punjab over the Study Period 1964-1983*

Year	Total Population (in millions)		
	Male	Female	Total
1964	11.93	10.32	22.25
1968	13.45	11.70	25.15
1973	15.58	13.63	29.21
1978	17.75	16.41	33.34
1983	20.01	17.63	37.64

* These figures were calculated by the authors using the normal compound growth rate formula: $P_t = P_1 (1 + \frac{Y}{100})^t$.

1/ Population Projections - All-India and States and Union Territories upto 1981 prepared by the Expert Committee on Population Projections in 1964.

These projections indicate that the population of Punjab will grow by nearly fifteen and a half million, of which number, perhaps, as many as three-quarters will remain rural-oriented. Punjab, in 1961, had about 20,300,000 persons of whom 80% (16,200,000) lived in rural areas. There is no pressing indication that this proportion will substantially change in the next 15 years, although there are reasons to expect that more persons will work in towns (as a result of urban economic pull) and that the composition of the rural labor force will undergo some change.

Punjab is known to be a land of owner-operated peasant farms, and this is reflected in the census figure wherein only about 10% of the rural labor force was found to be landless farm workers (500,000). The remaining 4,000,000 (defined as agricultural cultivators as opposed to agricultural labor) appear to be employed on their own farms. (Table 3-2).[2/]

The total figures, however, overstate the actual human energy available on farms. About 9% of the force is comprised (equally) of persons less than 15 and over 59 years of age. Such persons are imputed to contribute about half the energy possible from an adult worker. Women comprise 22% of the field force. An adult woman is able to exert about three quarter of the energy of an adult man. These two adjustments have been made in calculating the man-days of energy available to Punjab farms.

2/ The 1961 census reveals that 2.6 dependents (about 11,700,000) relied upon each of the 4,500,000 persons employed in agriculture.

Table 3-2 3/

Distribution of Agriculture Workers in Punjab actively engaged in agriculture in 1961 by sex and age groups and their percentage to total agricultural workers and total population.
(in thousands)

		Male	Female	Total
1.	Total agricultural workers of all ages	3,472	1,068	4,540
	a. Cultivators	2,989	1,007	3,996
	b. Agricultural laborers	483	61	544
2.	Agricultural Workers (active)			
	I. In the age-group of 15-59 yrs.	2,828	893	3,721
	a. Cultivators	2,418	841	3,259
	b. Agricultural laborers	410	52	462
	II. In the age-group of 0-14 yrs.*	127	67	194
	a. Cultivators	106	64	170
	b. Agricultural laborers	21	3	24
	III. In the age-group of 60 and above*	195	21	216
	a. Cultivators	179	20	199
	b. Agricultural laborers	16	1	17
	IV. Total Active Agricultural Workers	3,150	981	4,131
	a. Cultivators	2,703	925	3,628
	b. Agricultural laborers	447	56	503
3.	Percentage of (2) IV to 1.	90.7	91.9	91.0
	a. Cultivators	90.5	91.9	90.8
	b. Agricultural laborers	92.5	91.8	92.5
4.	Percentage of (2) IV to total Population (20,307)	15.5	4.8	20.3
	a. Cultivators	13.3	4.5	17.8
	b. Agricultural laborers	2.2	0.3	2.5

2/ Compiled by authors from 1961 census data.

* Half of each of these age groups do not participate actively in farm work; the active portion only are included here.

Before projecting the stock of energy available over the period 1964-83, a final adjustment is required. During the ten year period between censuses the percentage of cultivators to total population was seen to decline at a compound rate of 0.6 per cent annually. This rate would only become significant over a rather long period of time. However, the proportion of agricultural laborers declined by 5% annually. Such a decline, if maintained, is bound to greatly affect this laboring group over the coming fifteen years.

Within the landless laboring group a further shift has gone on. While male workers declined at a compound rate of about 2%, women laborers declined (over the ten year period) at the annual rate of 17%. Taking these shifts into account the following work force is postulated for the study period (Table 3-3).

Table 3-3

Projections for Agricultural Workers in the Punjab taking into account the trend observed between 1951 and 1961, in the proportion of agricultural workers to total population*
(in millions)

Year	Cultivators			Agricultural Laborers			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1964	2.87	1.03	3.90	0.46	0.03	0.49	3.33	1.06	4.39
1968	3.12	1.19	4.31	0.43	0.02	0.45	3.55	1.21	4.76
1973	3.45	1.40	4.85	0.39	0.01	0.40	3.84	1.41	5.25
1978	3.74	1.64	5.38	0.35	0.01	0.36	4.09	1.65	5.74
1983	4.00	1.88	5.88	0.32	-	0.32	4.32	1.88	6.20

* Computed by authors from census data.

The agricultural labor force will grow (according to our trend line) from 3,900,000 in 1964 to 5,880,000 in 1983. When compared with the total population projection over the same period, it is found that the rural working force will fall about 2% (from 17.5 to 15.5%), which is very little over the nearly 20-year period. During this period the proportion of landless labors will fall from 10% (1964) to 5% (1983).

When converted into terms of adult male units the following (Table 3-4) labor force is seen to exist. All of this labor, however, is not available for cultivation operations. A farmer, typically, divides his work time three ways. First, work connected with farm operations from preparatory tillage to the transport of the final product from the farm. Second, work connected with livestock, including all labor directed to the upkeep and care of draft animals and other livestock. Third, time connected with family affairs and business.

Table 3-4

Agricultural labor force projections in Punjab in terms of adult-male units*
(in millions)

Year	Cultivators	Agricultural laborers	Total
1964	3.64	0.48	4.12
1968	4.01	0.45	4.46
1973	4.50	0.40	4.94
1978	4.97	0.35	5.32
1983	5.41	0.32	5.73

*Calculated by the authors.

Farm management studies in Punjab (1963-64) show that the average farm worker (a permanent hired worker) worked 263 eight-hour days in the year. This time was divided among crop production (146 days), tending livestock (66 days) and family and social affairs (51 days). This annual input varied directly with the size of farm holding. On large holdings (50 acres) a farm worker puts in 317 days whereas only 251 days of labor were used on farms of less than five acres. A distinction was noted as well between cultivators and hired workers; the farmer works 256 days as opposed to 351 days for a hired person.

From these observations it can be concluded that a farm worker works an average of 17 days a month in activities directly related to crop production. There is, however, considerable monthly variation during sowing, harvesting and threshing when essentially social activities are postponed. Also time must be devoted to livestock. It is presumed that husbandry needs demand 10 days a month, every month. With these assumptions in mind the available labor force for crop production alone can be estimated (Table 3-5).

Table 3-5

Estimated human energy (in man-days) available for Crop Production in Punjab (rounded-off) (1964-1983)*

Year	Man Days/Years	Man days/month available
1964	82,400,000	6,866,000
1968	89,200,000	7,433,000
1973	98,800,000	8,233,000
1978	106,400,000	8,866,000
1983	114,500,000	9,542,000

*Calculated by authors from compiled data

These figures represent the stock of human energy available in a given year for crop production operations. By dividing these by 12 months the monthly stock of human labor in Punjab farm is produced.

b) The Draft-animal input

Draft animals comprise an integral part of the energy available to Punjab agriculture, and are the only prime movers widely used. Three different animals (bullocks, buffaloes and camals) are used, however, their pattern of use and utility varies greatly. Bullocks are the most important work animal and make up (1966) slightly over 80% of the total, and are used for all activities. A roughly equal number of camels (10%) and buffaloes (10%) exist in Punjab farms, but their utility is quite restricted. Buffaloes are mainly found where rice is grown (eastern and southern Punjab). Their primary activity is seed bed preparation. Camels are found in the drier areas where they are used for tillage operations and transport, but used principally for pumping operations (they will walk around a Persian wheel independently without supervision, unlike a bullock).

Neither animal is of much use for threshing operations. The camel has the wrong kind of foot and buffaloes are unable to work in the April-May heat when the main threshing activities occur. Bullocks are, therefore, the only draft animal that can be satisfactorily used for all operations in all seasons and this in part explains this wide use.

The basic sources of draft-animals data are the Five Year Livestock Census for the years 1945, 1951, 1956, 1961 and 1966. These serve as the basis for our projection of shift in animal population up to 1983-84. A compound growth curve was fitted to each animal and to the entire population to produce an estimate of the animals which can be available to farmers if no great changes occur in technology over the studied period (Table 3-6). Both separately and collectively, the trend figures were found to be very close to the observed, except in 1951. This year may be viewed as abnormal in that it was the first post-partition census and reflect the associated disturbance in livstock holdings.

Table 3-6

Total Projected Draft-animal force for Agriculture in the Punjab*
(in thousands)

Year	Bullocks	Buffaloes	Camels	Total
1964	2,450	269	240	2,959
1968	2,506	290	259	3,055
1973	2,599	324	281	3,204
1978	2,697	362	304	3,363
1983	2,798	404	330	3,532

* Compiled by authors from Livestock Census data

Like men, draft animals are used for three types of activity. First, all work directly related to crop production. Second, other farm work including transport of inputs to the farm and produce from it. Third, other work such as custom service, or family or social activities. Punjab Farm Management studies show that, for the studied sample, a pair of bullocks worked 147 days per annum on all activities. However, it was found that this level of utilization varied directly with the size of farm (Table 3-7) although the proportion of total time spent on crop production activities appear to be rather constant over much of the range.

Table 3-7

Average Annual Employment of a Pair of Bullocks in days per year devoted to farm activities*
(a day = 8 hours)

Holding size group (acres)	Crop Production	Farm work other than crop prod.	Other functions	Total	Crop prod: % of Total
0-5	77.29	18.32	20.65	116.26	66
5-10	119.21	11.45	9.30	139.96	85%
10-15	112.64	14.03	13.41	140.08	80%
15-20	129.21	13.25	10.77	153.23	85
20-30	127.65	16.42	15.08	159.15	80
30-50	149.70	12.59	10.30	172.59	85
50 and above	164.00	16.23	4.44	184.67	90
Average	120.89	13.94	12.29	147.12	

*Economics of Farm Management in the Punjab 1963-64 issued by the Economic and Statistical Organization, Government of Punjab 1966, page 41.

Larger farms are better able to utilise their bullocks than small, and use more bullocks. It is estimated that a pair of bullocks can cover about 10 acres and still perform needed work in a timely manner. Smaller farms must have a pair if they are to perform their operations at the optimum time, but must pay a higher average cost for this service. Very small farms (less than five acres) usually cannot support a team and must either lease more land, rent what is owned, or make do and try to hire custom time, accepting the late service as a cost of small scale operation.

The above period of annual use assumes that the bullocks are also used to pump water, which actively may demand as much as 30% of their working time on irrigated areas.

Given the various claims on their time, it is estimated that a team could be used about 20 days a month in activities directly related to crop production. With this assumption an estimate can be made of the stock of draft animal energy which will be available to farmers upto 1983. (Table 3-8).

Table 3-8

Projected Draft Animal Power in the Punjab*
(in '000 pairs of animals, except camels)

Year	Pairs of Bullocks and Buffaloes	Camels	Total	Draft Animal days available per mo.**
1964	1,360	240	1,600	32,000,000
1968	1,398	259	1,657	33,140,000
1973	1,462	281	1,743	34,860,000
1978	1,530	304	1,834	36,680,000
1983	1,601	330	1,931	38,620,000

* Compiled by authors from projections made from GOI census data.

**Draft animal days will be used synonymously with bullock days - from here on.

CHAPTER 4

Demand for Energy Using the Present Technology (and crop varieties)

With the information and projections regarding supplies of conventional energy and the intensity of monthly energy use per crop per hectare, a projection and analysis can be made of the level of energy demand over the period 1964-1984. It is assumed throughout this section that the present conventional technology will remain the dominant one in Punjab.

The requirements of energy per hectare were developed from farm management and cost of production studies conducted by the Punjab Government since the 1920s and supplemented by farm visits and readings on farm practices. The next, and more difficult step is the estimation of the area which will be under each crop over the studied period. To do this the pattern of growth of each crop are examined since 1951. In most cases the crop was found to follow different patterns over different periods. Whereas some crops such as bajra, pulses, gram and barley declined, others (wheat, maize, rice, groundnut and cotton) followed a generally upward movement. The growth rate of the most recent five year period was projected up to 1983-84 and the final total projected area compared with a projection of land use. As the former figure exceeded the latter, reconciliation was required. (The details of these are found in the appendix.) One crop, wheat, was found to increase greatly (142% on all land and 185% on irrigated land)! This seems a

very strong presumption and can only be defended on grounds of: lack of alternative winter crops, the relatively low risk associated with its culture, the assumption that favorable price ratios, and Punjab's comparative advantage in wheat production, will persist.

In addition to making crop projections, a complication was added by the need to account for the proportion of each crop which would be on irrigated and unirrigated land. Land use, irrigation potential and crop characteristics (technical and economic) entered into our judgement in this regard which details also are relegated to the appendix.

From this exercise a projected cropping pattern from 1904-1984 emerged which produced the area coefficients (Table 4-1)* used in making the per crop energy estimates (Table 4-2)*. By summing for each studied crop year across all crops, for each month, total demand figures for energy were calculated. These, of course, represent technical estimates, of demand for energy if farmers follow typically observed practices (Tables 4-3 and 4-4). To give an idea of the changes in energy demand over time, the comparative demand between 1964 and 1984 for each input are presented in Figure 4-1 and 4-2 and are compared with their respective associated supply of energy.

An examination of the two graphs immediately reveals where energy supply for both inputs has become a constraint, and a growing one. The pinch comes in October and November. But April, the period of wheat harvesting, is also seem to be on its way to becoming a labor scarce

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* These two tables are located in the appendix.

TABLE A-3

DEMAND FOR HUMAN ENERGY USING TRADITIONAL TECHNOLOGY

(1964-1984)

(millions of man-days; rounded-off)

Year/Month	July	August	September	October	November	December	January	February	March	April	May	June	Annual Supply of Energy
1964-65	49	32	46	87	75	27	35	22	20	32	65	30	82
1968-69	50	35	48	94	84	30	40	24	22	91	71	35	89
1973-74	56	40	55	105	89	32	42	26	23	97	77	36	99
1978-79	62	47	60	117	101	36	48	32	27	109	88	42	106
1983-84	68	52	64	126	111	38	52	35	29	118	95	44	115

Compiled by authors

TABLE 4-4

DEMAND FOR ANIMAL ENERGY USING TRADITIONAL TECHNOLOGY

(1964-1984)

(millions of bullock-days, rounded off)

Year, Month	July	August	September	October	November	December	January	February	March	April	May	June	Annual Supply of Energy
1964-69	21	11	22	36	28	10	8	5	5	16	20	12	32
1968-69	21	12	22	38	30	11	9	5	6	19	21	13	33
1973-74	24	13	25	40	33	12	9	6	6	21	23	14	35
1978-79	28	15	26	42	41	15	11	7	7	25	26	15	37
1983-84	31	15	28	45	46	16	12	7	8	28	28	16	39

Compiled by authors

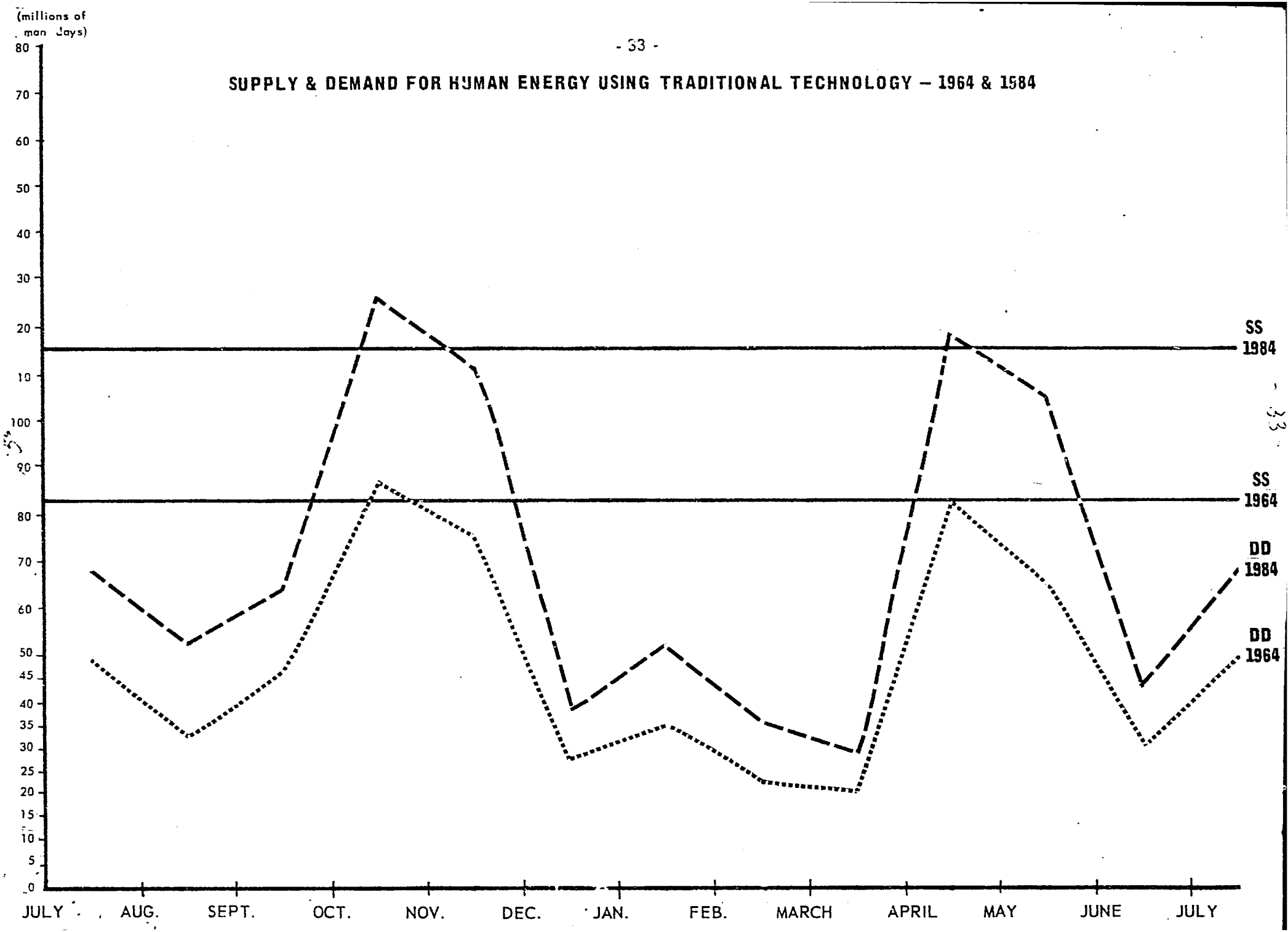
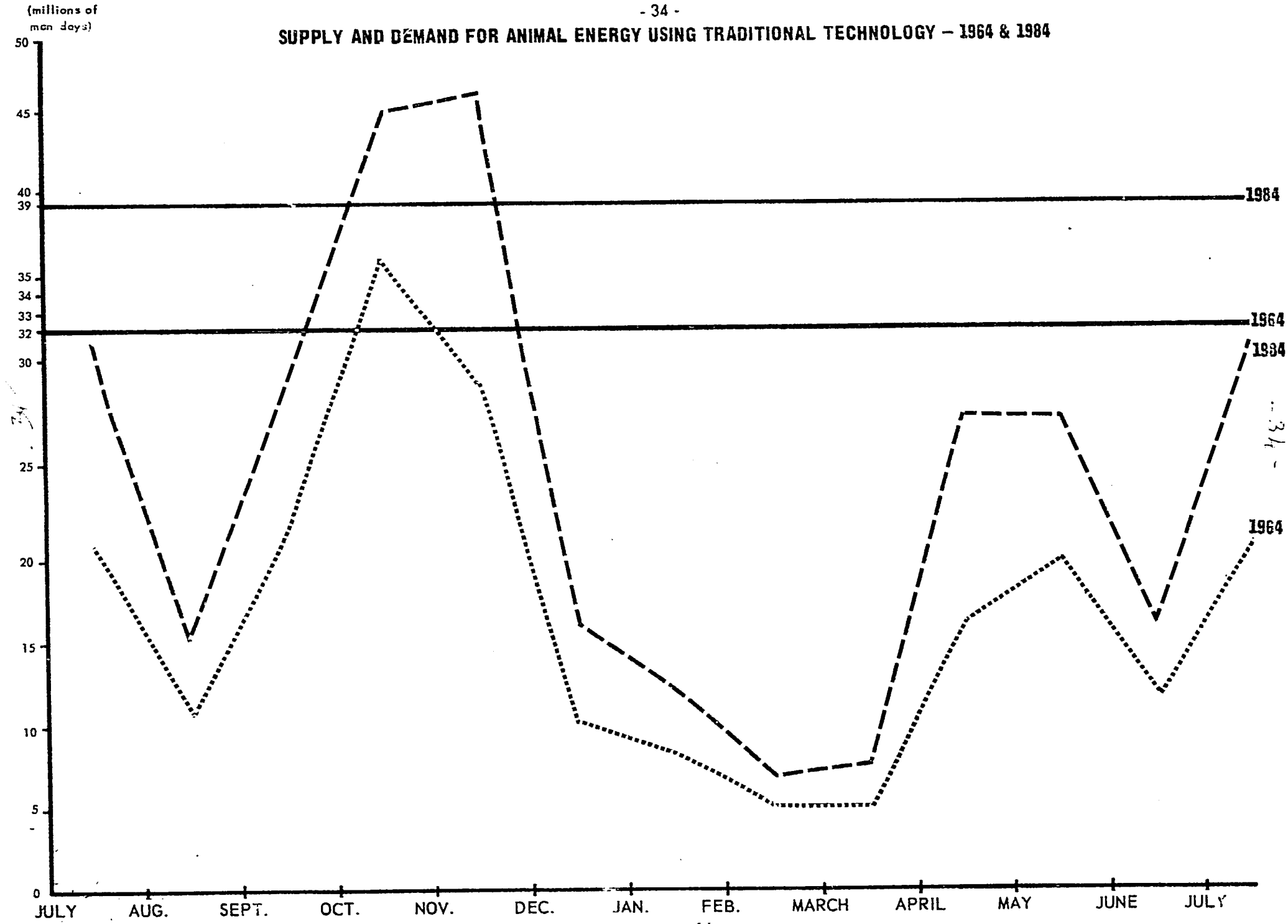

SUPPLY & DEMAND FOR HUMAN ENERGY USING TRADITIONAL TECHNOLOGY – 1964 & 1984
(millions of man days)
80
70
60
50
40
30
20
10
100
90
80
70
60
50
45
40
35
30
25
20
15
10
5
0
SS 1984
SS 1964
DD 1984
DD 1964
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY

FIGURE 4.

SUPPLY AND DEMAND FOR ANIMAL ENERGY USING TRADITIONAL TECHNOLOGY – 1964 & 1984



period as well. The demand for bullock energy only becomes a constraint at the autumn peak; but then it become a very severe one. Moreover, by 1984 the shortage of prime-mover energy will span the whole period from late September into December. However, labor supply too will become scarcer over a longer period of time. Why has the intensity of energy use become so much more marked?

It follows mainly from our assumptions, concerning the cropping pattern. The increased rabi plantings of wheat, immediately following increasing change under kharif crops (in turn permitted by increased irrigation) puts a very great burden upon the traditional energy sources. It must be remembered that with respect to wheat we are not at this point using HYV which will greatly increase (as we shall see) the demand for labor in April as a result of extra yields.

Punjab farmers at the present time allocate their available labor rather equally between planting, culture and harvest operations (35%, 27%, and 38% of the total man days respectively (Table 4-5). Over two-thirds of the available animal energy, however, is used for plowing and sowing alone; only 15% for pumping and cultural practices and 17% for harvest and thrushing. Most of the animal time in April-May (and about half the human energy) is required specifically for threshing which is heavily labor intensive and requires the services of the stronger men.

During the period of peak demand (Table 4-6) half of the human energy is required for harvesting right into December. Plowing begins

TABLE 4-5

Proportion of Total Annual Input from Conventional Sources

Time spent on major farm Operations

Input	OPERATION			
	Plowing & Sowing	Irrigation & Interculture	Harvest & Threshing	Total
Bullock	68	15*	17	100
Human	35	27	38	100

*Almost wholly for pumping

Calculated by the authors

TABLE 4-6

Proportion of Input Time Spent Monthly on Selected Operations

(at the present time)

	July	August	September	October	November	December	January	February	March	April	May	June
a) Plowing and Sowing												
Human Labor	85	85	45	36	32	-	-	50	70	17	-	40
Bullock Labor	90	85	75	87	83	-	-	63	65	6	28	86
b) Irrigation and Inter-culture												
Human Labor	15	15	55	16	24	55	52	50	30	13	14	60
Bullock Labor	10	15	25	7	10	60	49	37	35	63	-	7
c) Harvest and Threshing												
Human Labor	-	-	-	48	44	45	48	-	-	70	86	-
Bullock Labor	-	-	-	6	7	40	51	-	-	31	72	7
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100

Calculated by the authors.

with the monsoon period and is completed by November. Irrigation activities reach their peak in September-December and June. Sowing is also labor consuming, and must be done, in the case of wheat at the very period of peak need for labor for the kharif harvest.

Given the excess demand in October and November, it is the sowing and final plowing for wheat which is most likely to be postponed. Standing ripened crops in a field have precedence over the planting of the next crop. As energy is already becoming something of a constraint, through its effects on timeliness, a brief digression into the effect on yield seems appropriate.

Tardiness in sowing has a marked effect upon yield. Experiments conducted on various research stations in Northern India are suggestive in this regard (Table 4-7). The reduction in wheat yield, for example, when the crop was sown three weeks after the normal planting date was found to be p to nine quintals per hectare (12% below normal) and asmuch much as 28 quintals/ha. (41% below normal) if sowing were delayed six weeks. The potential additional yield if all wheat were planted on time is, therefore, considerable. The limiting factor is energy.

Energy is scarce because harvesting occurs immediately before the sowing time, which is a slow operation. Planting dates are pushed back as a result. The advent of shorter duration HYV will offset his limitation to some extent, but losses will nonetheless occur. Given the supply of bullocks and men likely to become available over the study period, the period October-November will become an increasingly critical one, and one which will entail the loss of considerable wheat production.

Table A-7

Average Yield of Wheat for Dates of Planting and Seed Rates (Q/ha.) (on alluvial soils)

Experiment Site	Date of Planting: Optimum	3 week lag	6 week lag
Bichpuri	34	29	6
Pusafarm	43	40	31
Masodha	45	38	30
B.H.U. Varanasi	41	32	21

Compiled by author from Table XIII (same title) coordinated Agronomic Experiments Schemes; Results of Model Agronomic Experiments Rabi 1967-68, ICAR, New Delhi

The demand for human energy in the peak autumn period will be 145% greater in 1984 than in 1964. The growth in demand for animal energy will be 165% over the same period. The growth in supply of human energy will be greater (140%) than that of animal (122%) but in neither case will the gap be narrowed. Indeed April, a break-even month in 1964, has become a deficit month in 1969.

In part this increasing deficit of energy is due to the growing importance of wheat, rice and maize amongst the foodgrains and of cotton especially among cash crops. As a result of this shift in crop pattern the resulting shortfall of energy in October will rise by 170%.

It is not immediately obvious given the apparent need which activity should be mechanized first. Different activities involve constraints, given their present technologies, at different times. With respect to human energy, whose input is spread over several activities in the fall, the relief of any one pressure on it could bring demand into line with supply. In April, harvest and threshing, are the central activities. Here high price of labor, and high rates of output (at a lower per unit cost) have already caused mechanical threshers to be substituted. We shall see their effect upon conventional inputs below.

Energy constraints, from a technical standpoint, are not the only factor which will determine the pattern of technical or input substitution. Relative pay-off between alternative systems even as both are technically adequate to perform the job at present, will play a major role. The best example is that of pumpsets. It is to this technical change that we now turn our attention.

CHAPTER 5

Changing Rural Technology - Its effects on demand for Energy: Energization of Wells

In this section the effect of the rapid energization of water supply on demand for energy will be examined. The outcome of this technical change will have an impact beyond the substitution of engines for bullocks. It will reduce the demand for bullocks resulting in a higher average cost of operation for this input. It will improve the opportunities for water management allowing more efficient use to be made of water thus lowering costs of production. Moreover, multiple cropping will be able to become much more widespread in the region. In this chapter these externalities will be touched upon; they are, however, very significant and should be borne in mind when considering the social-economic calculus relevant to this technological change.

Although, Punjab has been known as an irrigated region since the latter part of the 19th century, this water has in fact been mainly supplied from riverine sources (about two-thirds) through a network of canals. Until very recently well-irrigation from sub-soil water was limited by the unavailability of sufficient energy. Pumping was formerly done with the Persian wheel or by the Charsa. As recently as 1945, there were less than 500 pumpsets in operation. Beginning in the late 1950s the picture has changed dramatically. In 1956, there were about 12,000 operating sets; ten years later, over 66,000. At the present time there are more than 100,000 in use. By the end of the

Fourth Plan, this number is expected to treble. Hitherto, bullocks provided the bulk of pumping energy and pumping consumed about 15% of the annual bullock input. Nearly a third of the human energy expended in crop activities has been absorbed by activities directly associated with irrigation: operating the Charsa or wheel, opening and closing the bunds and so forth.[1/] Even with energization of pumping most of these activities will still be required; savings will come from the replacement of bullock by engine.

The pumpset appears on its way to become a most important element in Punjab agriculture. A projection was made to estimate the number of pumpsets which would be operational at the end of each forth-coming plan period (Table 5-1). This projection was prepared separately from those made by the Planning Commission and differs from them. It attempts to take into consideration land-use patterns and keep the projected total irrigated area consistent with these patterns. Our projection concludes that, by the end of the Sixth Planning Period (1983-84), as much as 93.6% of the total culturable area will be sown and that nearly 60% of this total area will be irrigated. At that time there will be an estimated 540,000 pumpsets operating on nearly 300,000 tubewells plus other water sources. These will enormously magnify the intensity of irrigation and may allow the gross cropped area to reach upto 200%

1/ Irrigation from a canal is much less consumptive of energy as the water flows into the field, by force of gravity.

TABLE [illegible]

Projected Progress of Energisation of Minor Irrigation in Punjab*

(1968-1984)

Year	Number of Pumpsets			(a) Estimated Area Irrigated by Pumpsets (ha.)	(b) Total Irrigated Area	Per cent of (b) to total irrigated area
	Diesel	Electric	Total			
1966	5,057	6,839	11,896	9[illegible],000	3,262,000	[illegible]6%
1966	25,428	40,956	66[illegible],640	530,000	3,551,000	16.7%
1968-69	30,000	77,000	107,000	860,000	3,856,000	22%
1973-74	75,000	227,000	300,000	1,8[illegible],000	4,257,000	43%
1978-79	100,000	350,000	450,000	2,561,000	4,585,000	59%
1983-84	110,000	430,000	540,000	2,690,000	4,939,000	60%

Estimated and compiled by authors.

(up from the present 140%) on the irrigated lands.

A single pumpset can replace two persian wheels, as its command area is roughly double the conventional water lift.[2/] Such a substitution would entail the complete replacement of the draft animals and half the human labor. In aggregate, this will represent a considerable saving to Punjab farmers. At the present time 25% of the total bullock contribution to wheat production is pumping. Substitution by a cheaper input will reduce the cost of wheat production, although to some extent this economy to farmers will be diluted by the need to keep the bullocks for other activities.

Some economy will accrue as well from improved timeliness due to the quicker application of water and the reduction in demand for bullocks time during the peak demand period in October-November. Rice, maize, cotton and cane require irrigation at this time as does the wheat seed bed, then in preparation. Costly (at this period) human time can be economized as well. The demand for energy from conventional sources for irrigation, per hectare, on the principal crops is shown in Table 5-2.

The displacement of labor and bullocks by pumpsets has been estimated (Table 5-3) and its effect upon total demand for those inputs presented in graph (Fig. 5-1). The displacement grows in magnitude over the studied period as the number of pumpsets increases. The displacement

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2/ We focus our attention upon the persian wheel as it is by far the most prevalent traditional form of energized well. Charsas account for only 10% of the total in Punjab.

TABLE 9.2

Total Demand for Energy Inputs for Irrigation in Punjab

(Input on ergs per ha.)

Crop / Input	Wheat	Gram	Cotton	Maize	Rice	Cane	Kharif fodder	Rabi fodder
Human	16.3	2.7	13.6	12.6	8.4	64.2	9.9	57.1
Animal	7.9	[illegible]	9.2	6.9	3.0	29.1	4.0	28.9

Calculated by the authors.

TABLE 5-3

Displacement of Irrigation Time due to Change in Technology

(millions of human hours)

Year	7	8	9	10	11	12	1	2	3	4	5	6
1964-65	.08	.45	.59	.66	.62	.61	.75	.71	.66	.58	.40	.51
1968-69	.14	.83	1.11	1.25	1.19	1.17	1.44	1.37	1.26	1.15	.78	.98
1973-74	.30	1.65	2.20	2.42	2.33	2.28	2.85	2.72	2.46	2.13	1.48	1.90
1978-79	.46	2.74	3.69	4.18	4.09	4.01	4.90	4.74	4.32	3.78	2.38	3.05
1983-84	.50	3.02	4.07	4.65	4.58	4.51	5.52	5.36	4.84	4.12	2.54	3.27

(millions of animal hours)

1964-65	.66	.24	.55	.70	.78	.57	.69	.78	.37	.46	.29	.42
1968-69	.11	.48	1.03	1.33	1.50	1.11	1.32	1.48	.71	.93	.56	.80
1973-74	.22	1.13	2.51	3.20	3.65	2.61	3.25	3.61	1.57	2.07	1.27	1.89
1978-79	.40	1.56	3.50	4.57	5.17	3.81	4.54	5.12	2.45	3.09	1.68	2.45
1983-84	.37	1.69	3.87	5.12	5.84	4.27	5.15	5.78	2.70	3.37	1.79	2.66

Calculated by the authors.

THE EFFECT OF ENERGIZATION OF IRRIGATION ACTIVITIES ON DEMAND FOR ENERGY FROM HUMAN AND ANIMAL SOURCES – 1983-84

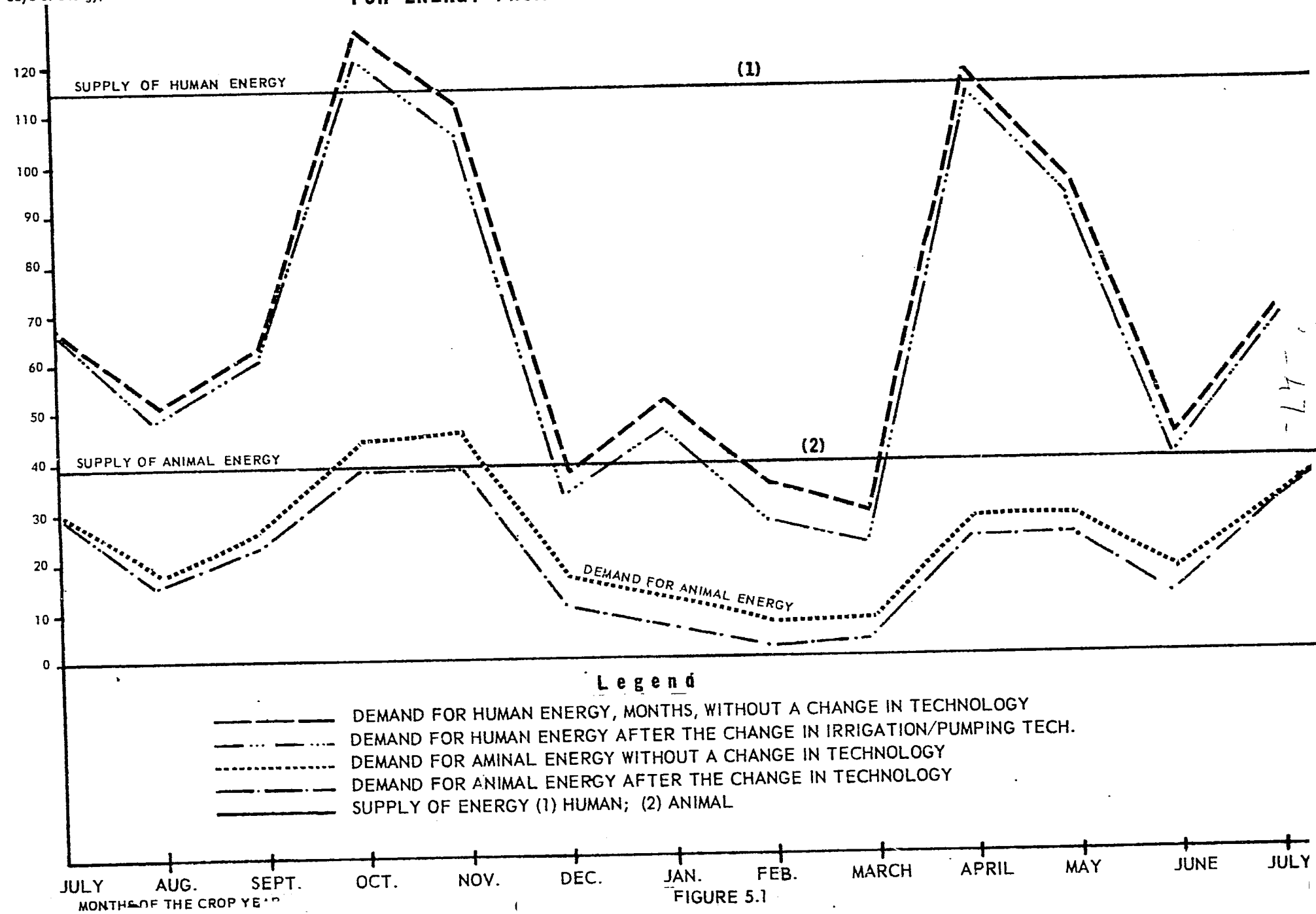

FIGURE 5.1

is particulary welcome, and evident in October-November. As a result of the increase in the number of pumpsets, excess bullock demand in this period will be eliminated by 1983-84. Human energy will also be in somewhat less demand but more efficiently used as the level of demand declines in that labor need not be used so extensively on activities which formerly required considerable effort at a busy time.

The use of these inputs will in fact decline during the entire year. What the social costs will be cannot be estimated, but it must be remembered that benefits will simultaneously flow from the innovation involving more efficiant use of land and water resources, cheaper agricultural products and the beginning of the displacement of costly draft animals from the rural scene in Punjab.

CHAPTER 6

Changing Rural Technology - Its Effects on Demand for Energy

High Yielding Varieties

Whereas input-demand-reducing pumpsets have come into widespread use recently, this change in technology has accompanied the simultaneous introduction of input-demand-increasing crop varieties. Since 1965, the high yielding varieties (HYV) of foodgrains have gained a rapidly growing share of crop level (Table 6-1). From 817,000 ha. under all types of HYV these varieties are expected by 1983 to account for almost all the foodgrains on irrigated land, to cover nearly 4,000,000 ha. Such a radical shift in variety is found to have some effect upon the quantity and pattern of energy needs.

The HYV are likely to have two obvious and immediate effects in this regard. The first, and most dramatic, will be that associated with extra yield. With wheat yields being as much as a double, extra labor will be required to harvest and thresh in about the same period of time, April-May. This extra demand appears in Table 6-2.[1/] The new varieties ought not of themselves to require a great deal more energy for planting, irrigation or inter-culture than crops presently on irrigated land.[2/] As fertilizers and pesticides are usually applied to these varieties some extra effort will have to be made, but these are likely to be marginal to existing practices and not greatly shift energy demand upward. There will be

1/Table 6-2 shows the figure for 1983-84 alone, the incremental changes appear, with associated technical changes on Table 8-1.

2/In the case of the dwarf wheat (Mellor reports) the number of plowings is increased, more weedings and irrigations are given, and harvest requires additional labor.

TABLE 6-1

Estimated Area Under H.Y.V.

Punjab and Haryana

1967-1983

(1000 ha.)

State	Year	CROP Rice	Wheat	Maize	Bajra	Total	
Haryana	1967-68	4	81	4	32	121	
	1973-74	121	528	41	300	1000	
	1978-79	170	761	60	425	1416	
	1983-84		(included in Punjab)				
Punjab	1967-68	16	607	28	45	696	
	1973-74	178	1194	210	61	1643	
	1978-79	255	1692	295	85	2327	
	1983-84	530	2518	430	510	4088	(inclusive of Haryana)

Compiled from Planning Commission (Perspective Division) "Crop Pattern for the decade ending 1978-79" and projection by authors.

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TABLE 6-2

Effect on Demand for Human Labor as a result of H.Y.V. Program

1983-1984

(millions of days of energy)

	July	August	September	October	November	December	January	February	March	April	May	June
DEMAND FOR HUMAN LABOR												
Level of Demand for Energy without H.Y.V.	67.74	51.88	64.43	126.0	111	37.72	52	34.77	28.99	117.83	95	44
Extra Demand due to H.Y.V.	-	-	-	-11.5	+17	+6.90	-	-	-	+18.3	+18.3	-
Net Demand due to H.Y.V.	67.74	51.88	64.43	114.5	128	44.62	52	34.77	28.99	136.13	113.3	44
DEMAND FOR ANIMAL ENERGY												
Level of Demand for Energy without HYV	30.86	16.99	27.65	44.50	45.71	16.09	12.08	7.10	7.50	27.65	27.59	16.16
Extra Demand due to H.Y.V.	-	-	-	-10.50	+4.00	+6.50	-	-	-	-	+5.30	-
Net Demand due to H.Y.V.	30.86	16.99	27.65	34.00	49.71	22.59	12.08	7.10	7.50	27.65	32.89	16.16

Calculated by the authors.

some shift in peak demand time as a result of the HYV. This will be mainly associated with wheat as it will be, by a considerable margin, the most important of the HYV crops sown. Consequently, the peak periods associated with wheat culture will be those affected most visibly by the change in technology.

The greatest period of peak energy use, for both conventional inputs, will be November (forward from October). In fact, the October use level will somewhat decline. This reflects the second effect of the HYV, namely, the change in duration of the crop due to the varietal change.

The HYV, due to its shorter duration, will be planted in November and still ripen in April. Instead of Octobers' having the greatest shortfall in energy supply, October demand will be met while November demand will exceed supply. The amount of this shortfall will to some extent be made up by the savings from the mechanisation of pumping, but not entirely.

HYV will, therefore, take some of the pressure off farmers during the Kharif harvest period, although these too will be somewhat larger due to varietal changes.

Demand for energy will markedly increase in April and May, for both inputs, reflecting greater yields. Given the supply projections for labor in Punjab there will be greater pressure than ever on the existing labor supply, causing sharply higher wages over the two month period,

when there will be a shortfall of over 17 million man days of energy. Tardy harvest will of course affect the final size of harvest and the ability to plant summer crop promptly.

CHAPTER 7

Changing Rural Technology Mechanization of Thrushing

Mechanical custom threshing of wheat by private entrepreneurs has come into Punjab rapidly in recent years. In 1968-69 an estimated 40% of the wheat crop will be threshed in this fashion. Formerly, threshing was done by the strongest men and the hooves of bullocks. Mechanical threshing can, therefore, be expected to have a strong displacement effect upon these conventional inputs. The cost-reducing effort of mechanical threshing is made apparent by the relative rates of threshing, at a time when conventional energy charges are at this peak. The mechanical thresher is roughly twice as productive as the traditional Phalla system of threshing, and requires only as third as much human labor and no bullock hours. Furthermore, the new system is not dependent upon the wind for winnowing, presently an important factor retarding the completion of the operation.

The rate at which introduction of the new system has occurred, the simplicity of the machinery involved (which is locally produced in the Punjab) and its obvious economy leads us to expect that fully 100% of Punjab wheat will be mechanically threshed within a decade (Table 7-1). Moreover, given the impact upon demand for labor during harvest the thresher will have an important role in reducing this excess. In addition, bullock demand will be reduced by a half during May.

TABLE 7-1

Effect of the Introduction of Wheat Threshers on Conventional Energy Requirements (assuming the HYV projections made in chapter 6) in the month of May.*

(millions of energy days)

Year	Estimated per cent of wheat treated by thresher	Savings in Conventional Energy		Final net demand (with HYV)	
		Human	Animal	Human	Animal
1968-69	40%	18	6	58	16
1973-74	80%	32	13	56	12
1978-79	100%	47	16	55	12
1983-84	100%	52	21	59	10

*Some small displacement occurs as well in April

Compiled and calculated by the authors.

SUPPLY AND DEMAND FOR HUMAN ENERGY – 1984
SHOWING THE EFFECT OF THE INTRODUCTION OF MECHANICAL THRESHING OF WHEAT AND HYV

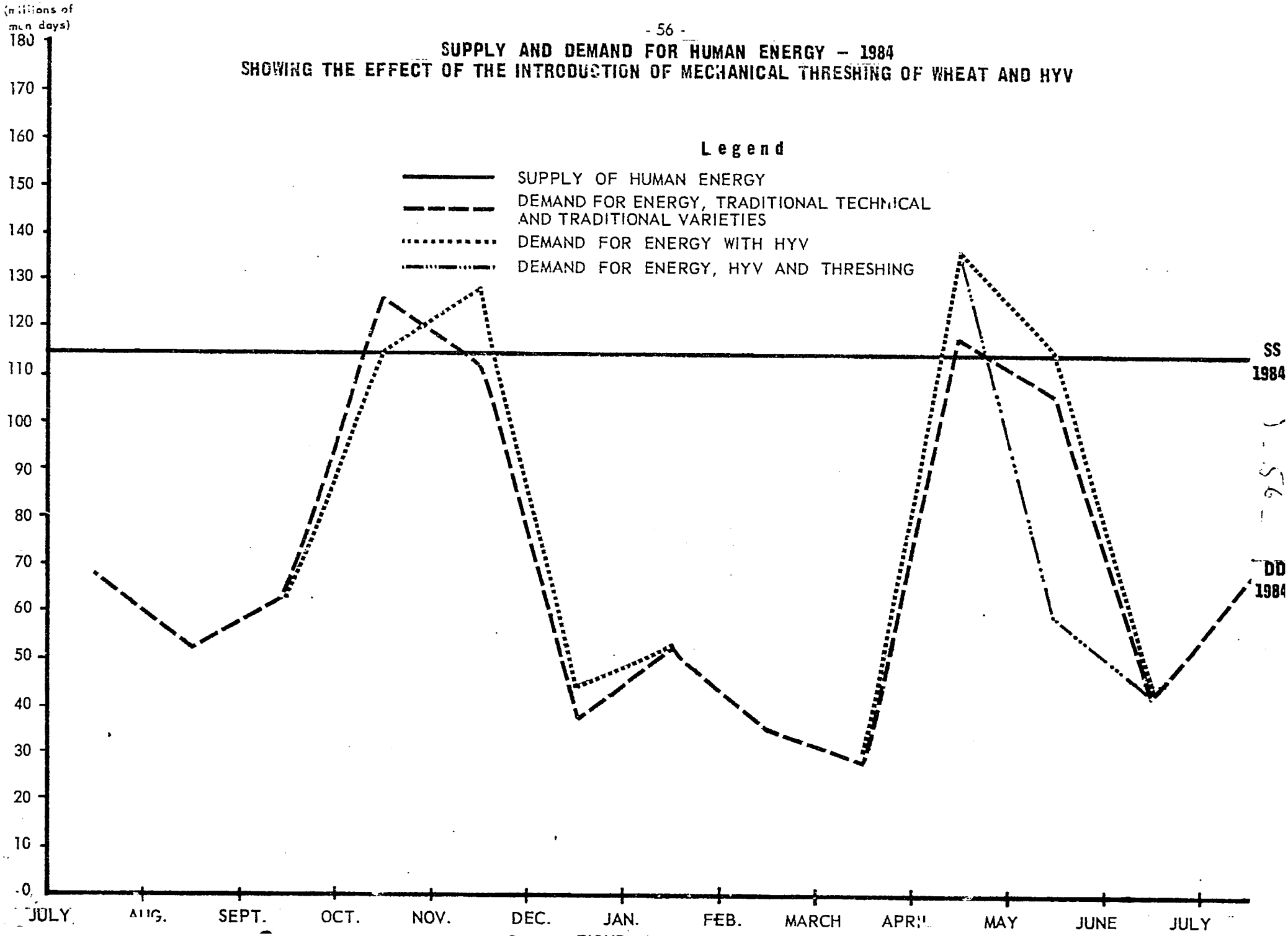
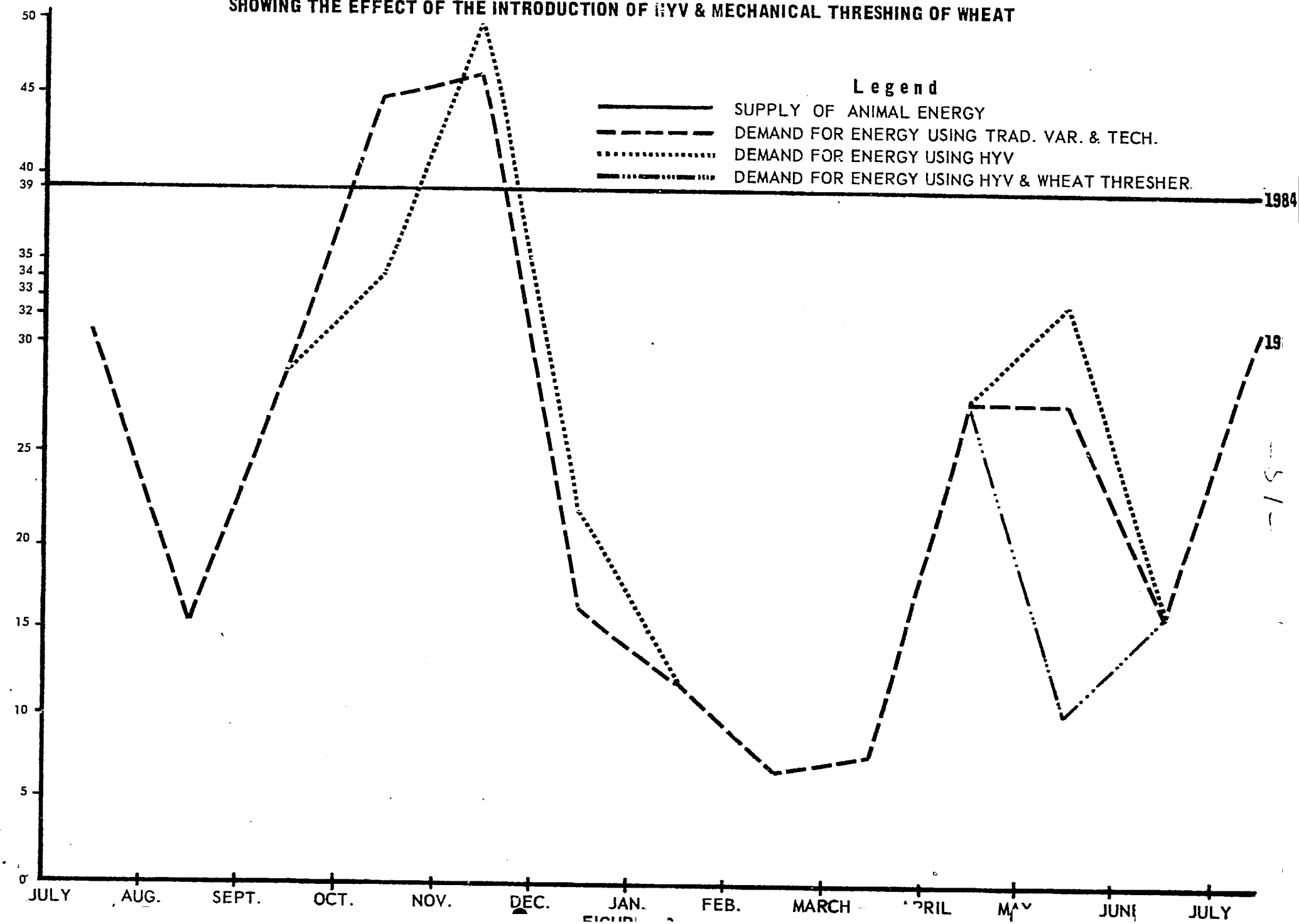


FIGURE 7-1

SUPPLY AND DEMAND FOR ANIMAL ENERGY – 1984

SHOWING THE EFFECT OF THE INTRODUCTION OF HYV & MECHANICAL THRESHING OF WHEAT



It is important to recall, given our interest in alternative public policies regarding mechanization, that this transformation is going on despite or in the absence of such policy. This represents a response by local entrepreneurs, using new technology to cope with a serious labor shortage and a costly activity to farmers. But the economies inherent in the alternative are so favorable as to cause an almost complete technical substitution to occur. The manufacture of threshers does not require a licence, involves little investment and are completely in the private sector. It would, furthermore, require a very considerable level of taxation to discourage their use (given their high pay-offs) even if such a policy were desirable.

The social costs in displaced labor may be great. This will be taken up in the next and final chapter when the net effect in ongoing technical changes will be considered.

CHAPTER 8

Cumulative Effect of Changes in Technology Upon The Demand for Conventional Sources of Energy

Implications for policy

This paper deals with the question of conventional energy inputs as a constraint to increasing agricultural production in the Punjab and with the pattern of their displacement as a result of the introduction of energized pumpsets, high yielding varieties and mechanized threshing. The paper also sets up an analytic framework within which the effect on energy demands of alternative technologies and crop patterns and rotations may be studied. (Table 8-1; Fig. 8-1, 8.2).

These three technical changes were selected to be introduced as incremental adjustments within the traditional productive pattern for two reasons. First, some data as to trade off between the substituting technologies exist. Second, and far more important, all of these technical changes are presently ongoing in the rural sector. Farmers have been accepting them as rapidly as they became physically available. Credit has been found when supplies of the input came within reach of the farmer. To a very significant degree these technical changes are "beyond" public policy in so far as policy is able to exercise a veto, or even much of a brake, upon their spread. Tractors and combines have not been included due to lack of time, but also because the growth of their use are very dependent upon public policy. Any analysis of the effect of latter two capital intensive inputs will have to take as its point of departure the demand for conventional inputs export of the three studied

Table 8-1

Cumulative Effect on Demand for Energy As a Result of Changing Technology in the Punjab

(millions of human labor days)

Item	Total	July	August	September	October	November	December	January	February	March	April	May	June
1964-65													
Demand as per T.M.	569.60	49.33	32.09	45.60	86.56	74.83	27.01	34.97	22.08	20.49	81.77	64.95	29.92
Trade-off due to pumps	-6.62	-0.08	-0.45	-0.59	-0.66	-0.62	-0.61	-0.75	-0.71	-0.66	-0.58	-0.40	-0.51
New level of demand	562.98	49.25	31.64	45.01	85.90	74.21	26.40	34.22	21.37	19.83	81.19	64.55	29.41
Trade-off due to HYV	-	-	-	-	-	-	-	-	-	-	-	-	-
New level of demand	562.98	49.25	31.64	45.01	85.90	74.21	26.40	34.22	21.37	19.83	81.19	64.55	29.41
Trade-off due to wheat thresher	-	-	-	-	-	-	-	-	-	-	-	-	-
New level of demand	562.98	49.25	31.64	45.01	85.90	74.21	26.40	34.22	21.37	19.83	81.19	64.55	29.41
1968-69													
Demand as per T.M.	621.55	50.10	34.85	48.23	93.75	83.70	29.85	39.91	24.18	21.39	91.00	71.29	33.30
Trade-off due to pumps	-12.67	-0.14	-0.83	-1.11	-1.25	-1.19	-1.17	-1.44	-1.37	-1.26	-1.15	-0.78	-0.98
New level of demand	608.88	49.96	34.02	47.12	92.50	82.51	28.68	38.47	22.81	20.13	89.85	70.51	32.32
Trade-off due to HYV	+12.50	-	-	-	-4.80	+1.90	+4.60	-	-	-	+5.40	+5.40	-
New level of demand	621.38	49.96	34.02	47.12	87.70	84.41	33.28	38.47	22.81	20.13	95.25	75.91	32.32
Trade-off due to wheat thresher	-17.52	-	-	-	-	-	-	-	-	-	-	-17.52	-
New level of demand	603.86	49.96	34.02	47.12	87.70	84.41	33.28	38.47	22.81	20.13	95.25	58.39	32.32
1973-74													
Demand as per T.M.	678.31	56.10	39.77	54.60	104.78	88.78	31.81	42.32	26.48	23.34	96.87	77.52	35.94
Trade-off due to pumps	-24.72	-0.30	-1.65	-2.20	-2.42	-2.33	-2.28	-2.85	-2.72	-2.46	-2.13	-1.48	-1.90
New level of demand	653.59	55.80	38.12	52.40	102.36	86.45	29.53	39.47	23.76	20.88	94.74	76.04	34.04
Trade-off due to HYV	+30.20	-	-	-	-8.30	+9.90	+5.00	-	-	-	+11.80	+11.80	-
New level of demand	683.79	55.80	38.12	52.40	94.06	96.35	34.53	39.47	23.76	20.88	106.54	87.84	34.04
Trade-off due to wheat threshers	-32.06	-	-	-	-	-	-	-	-	-	-	-32.06	-
New level of demand	651.73	55.80	38.12	52.40	94.06	96.35	34.53	39.47	23.76	20.88	106.54	55.78	34.04

Table 8-1 (contd.)

	Total	July	August	September	October	November	December	January	February	March	April	May	June
1978-79													
Demand as per T.M.	766.09	62.01	46.63	59.71	116.89	101.05	35.83	47.98	31.63	27.15	108.89	87.78	40.54
Trade-off due to pumps	-42.32	-0.46	-2.74	-3.69	-4.18	-4.09	-4.01	-4.90	-4.74	-4.32	-3.78	-2.38	-3.03
New level of demand	723.77	61.55	43.89	56.02	112.71	96.96	31.82	43.08	26.89	22.83	105.11	85.40	37.51
Trade-off due to HYV	+41.80	-	-	-	-10.30	+14.30	+5.90	-	-	-	+15.80	+15.80	-
New level of demand	756.57	61.55	43.89	56.02	102.41	111.26	37.72	43.08	26.89	22.83	120.91	101.20	37.51
Trade-off due to wheat thresher	-46.68	-	-	-	-	-	-	-	-	-	-	-46.68	-
New level of demand	718.89	61.55	43.89	56.02	102.41	111.26	37.72	43.08	26.89	22.83	120.91	54.52	37.51
1983-84													
Demand as per T.M.	831.68	67.74	51.88	64.43	126.02	111.05	37.72	52.25	34.77	28.99	117.83	95.08	43.92
Trade-off due to pumps	-46.98	-0.50	-3.02	-4.07	-4.65	-4.58	-4.51	-5.52	-5.36	-4.84	-4.12	-2.54	-3.27
New level of demand	784.70	67.24	48.86	60.36	121.37	106.47	33.21	46.73	29.41	24.15	113.71	92.54	40.65
Trade-off due to HYV	+49.00	-	-	-	-11.50	+17.00	+6.90	-	-	-	+18.30	+18.30	-
New level of demand	833.70	67.24	48.86	60.36	109.87	123.47	40.11	46.73	29.41	24.15	132.01	110.84	40.65
Trade-off due to wheat thresher	-51.74	-	-	-	-	-	-	-	-	-	-	-51.74	-
New level of demand	781.96	67.24	48.86	60.36	109.87	123.47	40.11	46.73	29.41	24.15	132.01	59.10	40.65

T.M. = Traditional Method
H.Y.V. = High Yielding Varieties

Table 8-2

Cumulative Effect on Demand for Energy As a Result of Changing Technology in the Punjab

(million of animal (pair) working days)

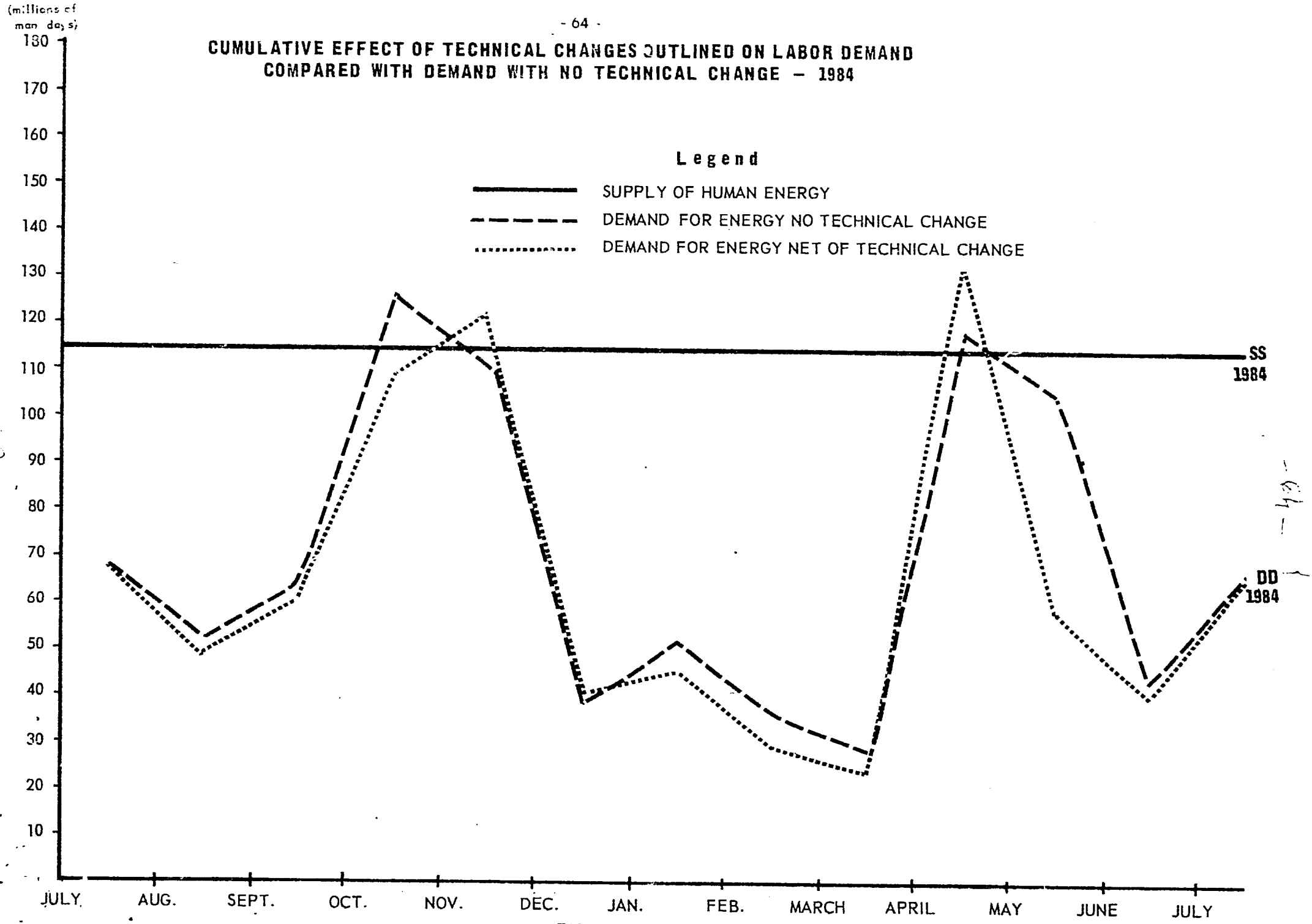
	Total	July	August	September	October	November	December	January	February	March	April	May	June
1964-65													
Demand as per T.M.	191.14	20.92	11.04	21.53	36.20	26.70	9.62	7.62	4.79	5.13	16.33	19.65	11.61
Trade-off due to pumps	-5.91	-0.06	-0.24	-0.55	-0.70	-0.78	-0.57	-0.69	-0.78	-0.37	-0.46	-0.29	-0.42
New level of demand	185.23	20.86	10.80	20.98	35.50	25.92	9.05	6.93	4.01	4.76	15.87	19.36	11.19
Trade-off due to HYV	-	-	-	-	-	-	-	-	-	-	-	-	-
New level of demand	185.23	20.86	10.80	20.98	35.50	25.92	9.05	6.93	4.01	4.76	15.87	19.36	11.19
Trade-off due to wheat thresher	-	-	-	-	-	-	-	-	-	-	-	-	-
New level of demand	185.23	20.86	10.80	20.98	35.50	25.92	9.05	6.93	4.01	4.76	15.87	19.36	11.19
1968-69													
Demand as per T.M.	208.61	21.96	11.83	23.23	37.78	30.25	11.06	8.59	5.25	5.60	19.19	21.26	12.61
Trade-off due to pumps	-11.38	-0.11	-0.48	-1.05	-1.33	-1.50	-1.11	-1.32	-1.48	-0.70	-0.93	-0.56	-0.80
New level of demand	197.23	21.85	11.35	22.18	36.45	28.75	9.95	7.27	3.77	4.89	18.26	20.70	11.81
Trade-off due to HYV	+1.50	-	-	-	-3.20	-0.70	+3.90	-	-	-	-	+1.50	-
New level of demand	198.73	21.85	11.35	22.18	33.25	28.05	13.85	7.27	3.77	4.89	18.26	22.20	11.81
Trade-off due to wheat thresher	-6.13	-	-	-	-	-	-	-	-	-	-	-6.13	-
New level of demand	192.60	21.85	11.35	22.18	33.25	28.05	13.85	7.27	3.77	4.89	18.26	16.07	-
1973-74													
Demand as per T.M.	227.33	24.39	13.13	24.81	40.43	33.40	12.16	9.31	5.58	5.94	21.27	23.02	13.89
Trade-off due to pumps	-26.98	-0.22	-1.13	-2.51	-3.20	-3.65	-2.61	-3.25	-3.61	-1.57	-2.07	-1.27	-1.89
New level of demand	200.35	24.17	12.00	22.30	37.23	29.75	9.55	6.06	1.97	4.37	19.20	21.75	12.00
Trade-off due to HYV	+3.40	-	-	-	-6.70	+2.70	+4.00	-	-	-	-	+3.40	-
New level of demand	203.75	24.17	12.00	22.30	30.53	32.45	13.55	6.06	1.97	4.37	19.20	25.15	12.00
Trade-off due to wheat thresher	-13.31	-	-	-	-	-	-	-	-	-	-	-13.31	-
New level of demand	190.44	24.17	12.00	22.30	30.53	32.45	13.55	6.06	1.97	4.37	19.20	11.84	12.00

Table 8-2 (contd.)

	Total	July	August	September	October	November	December	January	February	March	April	May	June
1978-79													
Demand as per T.M.	257.26	27.97	15.39	26.10	42.23	40.58	14.51	11.00	6.55	6.93	25.41	25.55	15.04
Trade-off due to pumps	-38.34	-0.40	-1.56	-3.50	-4.57	-5.17	-3.81	-4.54	-5.12	-2.45	-3.09	-1.68	-2.45
New level of demand	218.92	27.57	13.83	22.60	37.66	35.41	10.70	6.46	1.43	4.48	22.32	23.87	12.59
Trade-off due to HYV	+4.50	-	-	-	-9.10	+3.40	+5.70	-	-	-	-	+4.50	-
New level of demand	223.42	27.57	13.83	22.60	28.60	38.81	16.40	6.46	1.43	4.48	22.32	28.37	12.59
Trade-off due to wheat thresher	-16.43	-	-	-	-	-	-	-	-	-	-	-16.43	-
New level of demand	206.99	27.57	13.83	22.60	28.60	38.81	16.40	6.46	1.43	4.48	22.32	11.94	12.59
1983-84													
Demand as per T.M.	279.78	30.86	14.99	27.65	44.51	45.70	16.09	12.08	7.10	7.50	27.65	27.59	16.16
Trade-off due to pumps	-42.61	-0.37	-1.69	-3.87	-5.12	-5.84	-4.27	-5.15	-5.78	-2.70	-3.37	-1.79	-2.66
New level of demand	237.17	30.49	13.30	23.78	39.39	39.86	11.82	6.93	1.32	4.80	24.28	25.80	13.50
Trade-off due to HYV	+5.30	-	-	-	-10.50	+4.00	+6.50	-	-	-	-	+5.30	-
New level of demand	242.47	30.49	13.3p	23.78	28.89	43.86	18.32	6.93	1.32	4.80	24.28	31.10	13.50
Trade-off due to wheat thresher	-21.14	-	-	-	-	-	-	-	-	-	-	-21.14	-
New level of demand	221.33	30.49	13.30	23.78	28.89	43.86	18.32	6.93	1.32	4.80	24.28	9.96	13.50

T.M. = Traditional Method
H.Y.V. = High Yielding Varieites

CUMULATIVE EFFECT OF TECHNICAL CHANGES OUTLINED ON LABOR DEMAND COMPARED WITH DEMAND WITH NO TECHNICAL CHANGE – 1984



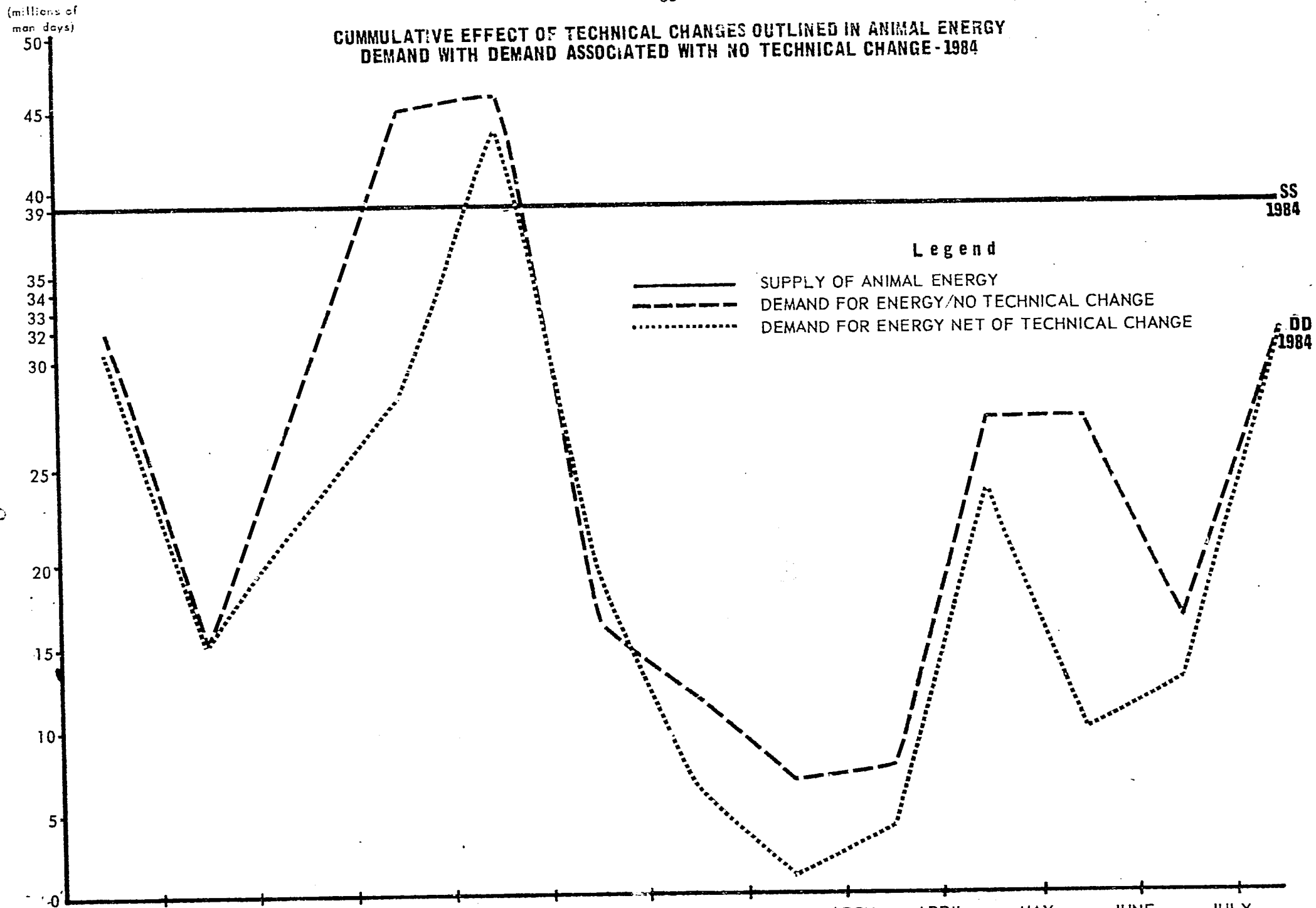

(millions of man days)
CUMMULATIVE EFFECT OF TECHNICAL CHANGES OUTLINED IN ANIMAL ENERGY DEMAND WITH DEMAND ASSOCIATED WITH NO TECHNICAL CHANGE-1984
50
45
40
39
35
34
33
32
30
25
20
15
10
5
0
SS 1984
DD 1984
Legend
SUPPLY OF ANIMAL ENERGY
DEMAND FOR ENERGY/NO TECHNICAL CHANGE
DEMAND FOR ENERGY NET OF TECHNICAL CHANGE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY

FIGURE 3.2

inputs because of this very rapid appearance as a permanent feature in the rural economy.

None of the three studied technical changes are likely to be either reversed by public policy or their rate of spread diminished for reasons of fear of labor displacement, which we have found to be not insignificant. The HYV program will be pushed in the interest of national self-sufficiency. In fact, this program is job-creating, in excess of supply, as a result of greatly increased farm yields. The program cannot, however, be successful unless its acreages are water-assured which means that energized pumping must be encouraged by public policy as well. Pumps reduce the demand for conventional energy by about 10% annually. The extra yields possible from the HYV require a much larger labor force for their harvest, however, mechanical threshing will reduce the labor and bullock energy needs for the wheat crop by about half during the wheat harvest period. Mechanical threshing as an input has developed largely outside of public policy in response to need. The demand for a cheaper and more productive technology was largely met from local resources and technology. Because so much of the impetus behind the introduction of these new technical inputs seems irreversible we believe our general estimates of the demand for conventional energy are not unrealistic and variance will accrue more from misjudgement as to cropping pattern than to rates of substitution.

The supply of energy is another matter. Insofar as, Punjab remained a closed economy, our supply projections seem defensable. However, in 1968-69, movements of short-term agricultural labor from Rajasthan have been reported. Furthermore, there has been some movement of workers from urban areas during the harvest periods within Punjab. These factors will act to raise the supply of labor somewhat, but there is reason to believe that, on logistical grounds, the deficit supply cannot be made good by labor importation alone. The shortfall in labor supply in April-May is of the magnitude of nearly 18,000,000 man-days which would require nearly a million extra workers in that one month alone to satisfy. Moreoever, a half million extra workers will be needed in November. It seems very doubtful that such large but short-term labor migration could be managed given the opportunity now opening to farmers to substitute these persons by machinery.

The general pattern of energy demand does not change greatly between 1964-1984 as a result of shifts in crop pattern and increased mechanization. In absolute terms, during peak periods, the level of demand for human energy increases 125% in October and 165% in April as a result of these shifts. Bullock demand increased by 165% in November, largely as a result of the HYV. These varieties are responsible for the increased labor demand in April as well, but mechanical threshers have acted to greatly reduce demand in for labor in May.

We may now turn to the question posed at the beginning of this exercise - when and under what circumstances will conventional energy supply become a constraint. The answer is now obvious. The supply of energy of both human and animal inputs would become inadequate to cope

with the mounting demand for food even with no varietal or other technical changes. These changes accentuate and to some degree shift the pattern of shortage, but do not of themselves create the situation. The shifts in technology studied here have, however, the effect of increasing the average unemployment of both factors over the year, especially in the case of bullocks, whose entire level of demand over the year will be depressed. In the case of human labor the twin peaks of supply shortage remain, but the troughs are deeper and the slopes steeper. Fluctuations in labor demand will, therefore, become much sharper. Such movements may well act to increase the rate of exit of landless labors if off-farm opportunities exist. The magnitude of the shortfall make it unlikely that sufficient out of state labor can be easily imported to cope with the two brief periods of shortage. This means that wages, especially in April, will continue high for a few weeks and farmers will continue to seek cheaper alternatives. Custom combine service will likely become very appealing under these circumstances for all activities.

There will probably be less technical need for tractors to meet the needs of post-kharif plowing as much of the bullock deficit will be diminished by the introduction of short-duration HYV. However, given the lower level of average bullock use, the average cost per farm to operate them will increase as they are displaced by pumpsets and threshers. For three months, they will have almost no directly productive activity at all. Such economies will become powerful arguments, especially to the smaller farmers who can barely manage a pair, to use custom tractor time for November and June plowings if this is available.

Which labor will be displaced by these farms of mechanization? On the whole, these innovations will not greatly depress the average demand for labor except in May. Landless labor, already a declining group in Punjab will likely be hit the hardest, but will still be needed during the peak periods. In fact more labor will be needed than ever before at harvest. The decline in labor use in the winter months comes mainly from the mechanization of irrigation. This will affect able bodied men who operated the charsa and boys behind bullocks, usually with one pump replacing one man.

The thresher will be the most labor displacing - and such activities usually involved strong men. Hired persons will probably be the first to go, but it will doubtlessly mean less employment for the farm family in this activity as well. It seems clear, however, given the extra productivity of the mechanical thresher, that the family income to the farmer will be higher even with the shorter working period required to perform the operation. In fact, the rate of return to the farm should on the average be higher over the year, despite the lower family labor input, due to the economies deriving from the new technology. In this context the lowering of labor input may be viewed as an increase in standard of living associated with the increased productivity of farm labor.

In Punjab, we estimate that the landless labor groups will become quite small by 1984. Therefore, the immediately displaced group in the state is not likely to be very large. There is every reason to believe

that the increased level of rural activity and prosperity will be associated with an equivalent activity in the urban sector which should be able to absorb both landless labor and some members of the farm operators' families. The social costs involved with this level of mechanization are not, therefore, altogether clear.

The benefit to society from studied forces of mechanization seem clear and potent. Yields will be favorably affected by prompt plowing, and threshing. Moreover, by shortening the period required for any single crop the opportunity for a post-rabi and post-kharif crop will become real and from this the provision of larger amounts of cheaper agricultural goods will be a direct benefit to society as a whole.

A great deal of discussion has centered about the issue of the desirability to mechanize Indian agriculture. The point is made in this paper that substantial mechanization with deep seated effects on the pattern of employment of conventional inputs is going on, rapidly. Several new changes are in prospect as well. Herbicides, for example, which will replace a great deal of intercultural labor-intensive activities are now coming onto the scene.

The continued development of bullock-displacing energy inputs make this conventional input more of an anachronism in Punjab. By 1984 the major bullock activity will be plowing. The question may well be raised before then, can Punjab farmers in their desire to multi-crop afford such a slow and expensive prime mover? Given the 16% of gross cropped area under fodder crops for animals, excellent economics reasons will

urge their replacement by tractors. We do not have the coefficients immediately available to estimate the ratio of substitution of bullock and man with respect to tractors. Bullocks, however, should be rapidly replaced if a cheap reliable source of custom tractor service are available, which service would be especially beneficial to the small Punjab farmer.[1/] The tractor would really be replacing a high cost, low productivity input, which could yield probably substantial social benefits from extra output. The tractor is one input which will be highly dependent upon public policy for its rate of introduction.

The combine is the second capital intensive input whose future lies in large measure in public hands. There seems to be a somewhat weaker argument for the large scale introduction of combines. The machines doubtless would economize on farm labor during the still deficit harvest period. On the other hand one important part of the combine activity is already being performed by the mechanical thresher. As the combine does not have yet chaff cutters attached, this important function must still be left to labor. Consequently cutting is the only extra activity that the combine would mechanize. Even this activity is on the verge of greater mechanisation as tractor drawn reapers are being developed. Mechanical reaping is a further area which may be revolutionized by the provision of custom tractor service.

1/ An additional benefit can accrue as well. Draft animals presently used are dual-purpose: draft and milk. If the former condition need no longer be met, milk-specialist animals could be substituted.

Table 4.4

Projected Cropping Pattern for Punjab
(in thousand hectares)

		1964-65		1968-69		1973-74		1978-79		1983-84	
		Total	Irrigated	Total	Irrigated	Total	Irrigated	Total	Irrigated	Total	Irrigated
I	CEREALS										
	Jowar & Bajra	1245	158	1102	152	977	140	1055	147	1054	157
	Maize	591	262	625	281	675	305	708	388	744	444
	Rice	526	377	566	425	673	516	780	663	862	750
	Wheat	2456	1396	2650	1578	2905	1888	3211	2268	3491	2618
	Barley	162	56	139	46	126	42	120	40	120	40
	Other Cereals	36	3	26	3	22	2	20	2	20	2
	Total	5014	2232	5088	2165	5476	2943	5924	3508	6311	4011
II	PULSES										
	Gram	2030	493	2110	528	2007	502	1956	489	1956	489
	Others	171	25	130	20	107	16	92	14	83	12
	Total	2251	518	2240	548	2114	518	2048	503	2049	501
III	OILSEEDS										
	Groundnut	136	7	138	7	168	8	194	10	214	10
	Rape Mustard and Others	251	-	391	-	416	-	418	-	431	-
	Total	387	7	529	7	584	8	612	10	645	10
IV	COTTON	662	633	771	740	824	858	1011	970	1116	1066
V	SUGARCANE	270	218	270	221	277	240	284	240	292	247
VI	ALL FOODGRAINS	7265	2750	7328	3013	7590	3464	7972	4011	8360	4512
VII	NON-FOOD CROPS	1507	887	1816	1264	2497	1222	2922	1954	2938	2125
VIII	ALL CROPS	10121	4492	10714	5242*	11542	5784*	12144	7155*	11609	7950
IX	NET AREA SOWN	7649	4285	7607	4256	7949	4257	8062	4525	8144	4959

*Compiled by authors and from Planning Commission (P.P. Division). A note on perspective crop pattern for the decade ending 1978-79

Table 4.2 (a)

Monthly Employment of Labor on Important Crops Irrigated (million man-days/ha)

	July	August	September	October	November	December	January	February	March	April	May	June
Wheat	-	-	2.0	8.0	13.5	9.0	9.8	3.3	3.3	12.5	15.5	-
Gram	-	-	7.0	3.0	-	3.0	1.5	-	1.8	5.5	7.0	-
Am. Cotton	2.0	3.7	6.0	24.0	8	2	-	-	-	19.0	10.0	13.0
Desi Cotton	14.8	3.0	8	20	7.0	-	-	-	-	-	17.5	11.0
Maize	7.6	20	16	15	-	-	-	-	-	-	-	19.0
Rice	23.6	17.0	9.5	13.0	7	-	-	-	-	-	-	-
Cane	17.0	8.0	10.6	15.0	9.0	42.0	46.0	20.0	53	21	-	14.0
Rape	-	-	11	4	4	4	1.0	-	-	-	-	-
Kharif fodder	2.0	2	2	2.2	-	-	-	-	-	4.0	4.0	8.0
Rabi fodder	-	-	7	7.0	15.0	-	2.0	5.0	9.0	7.0	12	-

Table 4.2(b)

Monthly Employment of Labor on Important Crops

Non-irrigated (million man-days/ha.)

	July	August	September	October	November	December	January	February	March	April	May	June
Wheat	-	-	9	10.2	2.1	2.9	-	-	-	12.3	15	-
Gram	-	-	8.3	3.0	-	-	-	-	3.2	4.7	7.0	-
Maize	15	7	15	5	-	-	-	-	-	-	-	19
Rice	20.8	17	6	9	4.0	-	-	-	-	-	8	8.8
Cane	6.8	-	-	-	19	40	40	15	15	8	-	2
Bajra	10	2	1	3.4	6.0	2	-	-	-	-	-	4
Groundnut	12.2	8	8	5	15	-	-	-	-	-	-	4
Kharif fodders	4	-	-	2.1	-	-	-	-	-	-	-	-

Table 4.21(a)

Monthly Employment of Bullock Labor on Important Crops[1]

Irrigated (million bullock-days/ha.)

	July	August	September	October	November	December	January	February	March	April	May	June
Wheat	-	-	0.7	5.0	9.7	4.0	1.7	1.7	1.6	1	5.9	-
Gram	-	-	3.0	2.0	-	.3	-	-	-	-	2.3	-
Am. Cotton	3.0	1.0	-	-	-	-	-	-	-	12.0	1	9.3
Desi Cotton	1.0	1.0	1.0	-	-	-	-	-	-	-	11.0	2.5
Maize	2.0	2.0	2.0	2.0	-	-	-	-	-	-	-	14.2
Rice	9	5	2	2.3	-	-	-	-	-	-	-	-
Cane	12.7	6.0	7.0	-	6.0	8.0	12.0	7.0	15.0	2.0	-	7
Rape	-	-	6	2	2	2	1	-	-	-	-	-
Kharif fodders	1	1	1	1	-	-	-	-	-	2	3.6	4
Rabi fodder	-	-	2.6	2.3	7	-	-	3.0	9.0	3.0	6.0	-

1/ expressed in "bullock-pair" days

Table 4.2(d)

Monthly Employment of Bullock Labor on Important Crops[1/]

Non-irrigated (million bullock-days/ha.)

	July	August	September	October	November	December	January	February	March	April	May	June
Wheat	-	-	6.2	9	-	-	-	-	-	1.0	5	-
Gram	-	-	5	3	-	-	-	-	-	-	1.9	-
Maize	1	-	-	.1	-	-	-	-	-	-	-	13
Rice	10	3.3	-	1	-	-	-	-	-	-	1.2	-
Cane	-	-	-	-	5	11	11	8	9	-	-	-
Bajra	4	1.9	1	-	1	-	-	-	-	-	-	4
Groundnut	2	1.4	-	-	-	-	-	-	-	-	-	3
Kharif Fodder	3	-	-	.9	-	-	-	-	-	-	-	-

1/ expressed in "bullock-pair" days

Appendix

Methodology Employed in Determining Energy Needs

The energy needs for crop production in Punjab agriculture have been determined on the basis of:

(1) physical inputs of labor (human and animals) required to produce each of the principal crops; and

(2) expected cropping pattern of the state over the projected years.

As far (1) the main sources of information are:

(a) "Studies in the Economics of Farm Management in the Punjab", 1954-55 to 1956-57 and 1961-62 to 1963-64, conducted under the aegis of the Directorate of Economics and Statistics, Ministry of Food and Agriculture, GOI.

(b) "Farm Accounts in the Punjab", an annual series (since the 1920s') on economics of farm business, published by the Economics and Statistical Advisor to the Punjab Government; and

(c) "Cost of Production of Crops in the Punjab for the years, 1961-62 to 1965-66", unpublished report of the Economics and Statistical Organization of Punjab Government.

The data provided in the last publication is the most recent and as such has been mainly relied upon to work out the estimates of labor requirements of crops for the various agricultural operations. These figures have further been split up amongst the months according to the time of performing these operations. The final position, as it has emerged, is given in tables 4.2.(a), (b), (c) and (d).

The determination of cropping pattern over the study period has involved two steps:

(1) estimation of land-use potential; and

(2) projection of areas under different crops.

The Punjab statistics from 1951-52 to 1964-65 show that:

(a) while total available land declined from 8.8 million hectares in 1952-53 to 8.6 million hectares in 1964-65, the net area sown increased from 6.4 million hectares to 7.6 million hectares during this period, as the result of decrease in culturable waste land from 1.1 million hectares to 0.5 million hectares and in fallow lands from 1.2 million hectares to 0.45 million hectares.

(b) the percentage of net area sown to total available land increased from 72.59 per cent in 1951-52 to 88.90 per cent in 1964-65.

Keeping these trends in mind land-use area projections for the years under study have been made (Table Appendix I).

As the result of a decrease in the uncultivated culturable waste and fallow lands, the net sown area is expected to increase from 7.8 million hectares in 1968-69 to 8.1 million hectares in 1983-84. The total area of land available for cultivation is likely to remain, more or less, stable, near 8.6 million hectares, less some acreage absorbed in the process of urban growth.

At present over 90% of the total available land is put under crops. It is estimated that during the next 15 years land utilization may reach 95% of the possible cultivable area.

Table Appendix I

Projected Land-Use Patterns in Punjab 1968-1984*

Land Classification Year	Uncultivated arable land excl. fallow '000 ha.	Compound Growth Rate	Fallow land '000 ha.	Compound Growth Rate	Net area sown '000 ha.	Compound Growth Rate	Total Arable Land	Percentage of net area sown to total arable land
1951-52	1212	-	1212	-	6422	-	8,846,000	72.59
1955-56	963	-5.9	603	-19.0	7201	+2.9	8,767,000	82.13
1960-61	609	-9.5	544	- 2.1	7422	+0.6	8,575,000	86.55
1964-65	502	-5.0	453	- 4.7	7649	+0.6	8,604,000	88.90
1968-69	413	-5.0	380	- 4.5	7811	+0.5	8,604,000	90.78
1973-74	339	-4.0	312	- 4.0	7953	+0.4	8,604,000	92.43
1978-79	279	-4.0	263	- 3.5	8062	+0.3	8,604,000	93.70
1983-84	241	-3.0	227	- 3.0	8136	+0.2	8,604,000	94.56

* Calculated by the authors.

A similar procedure to the one adopted for projecting land-use potential has been followed in determining the perspective cropping pattern over the study period. The compound growth rates observed up to 1964-65 and those adopted for the subsequent years are noted in Table Appendix II.

The observed values during the 14 year period ending 1964-65, indicate that the area under all crops, excepting gram and millets, is showing an upward trend. Wheat, which is the principal cereal of the state, has increased in area at almost a uniform annual growth rate of over 2.2 per cent between 1955-56 and 1964-65. In view of overwhelming importance of this crop in the agricultural economy of the state, the pivotal position it occupies in a wide range of multiple-crop rotations in irrigated areas and absence of any other alternative competing crop, which can be extensively grown in winter season, it is envisaged that the area under this crop will continue to increase at an annual growth rate of 2 per cent up to 1978-79 and at 1.5 per cent thereafter. This estimate is rather modest for the period 1964-65 to 1968-69. The indications are that the growth rate during this period will be much above the assumed rate, inasmuch as by 1967-68, the area under this crop in the new States of Punjab and Haryana, had already exceeded the 1968-69 projection for the erstwhile Punjab, which besides the two new states, included some areas transferred to Himachal Pradesh.

The area under rice has more than doubled itself between 1951-52 and 1964-65 and its annual growth rate between 1960-61 and 1964-65 was 4.7. With increased irrigation facilities, area under this crop is also expected

Table Appendix II

Observed and Projected Changes in Growth Rates of Cropped Area under Major Crops in Punjab*

Crop	Observed Compound Growth Rate			Projected Compound Growth Rate			
	1951-52 to 1955-56	1955-56 to 1960-61	1960-61 to 1964-65	1964-65 to 1968-69	1968-69 to 1973-74	1973-74 to 1978-79	1978-79 to 1983-84
Maize	+ 1.0	+ 6.1	+ 1.6	+ 1.5	+ 1.5	+ 1.0	+ 1.0
Rice	+ 2.4	+ 9.8	+ 4.7	+ 4.0	+ 3.5	+ 3.0	+ 2.5
Wheat	+ 3.8	+ 2.2	+ 2.3	+ 2.0	+ 2.0	+ 2.0	+ 1.5
Gram	+ 2.8	- 1.5	- 2.3	+ 0.4	- 2.0	- 0.6	-
Groundnut	+ 2.6	+ 2.4	+ 4.5	+ 4.0	+ 3.0	+ 3.0	+ 2.0
Cotton	+13.4	+ 0.7	+ 5.2	+ 3.5	+ 3.0	+ 2.5	+ 2.0
Sugarcane	+ 2.5	+ 9.1	+ 0.1	-	+ 0.5	+ 0.5	+ 0.5
All Crops	+ 3.3	+ 0.5	+ 1.0	+ 1.0	+ 1.5	+ 1.5	+ 1.5

* Calculated by authors.

to go up, but at a somewhat lower rate than in the past. Amongst the cash crops, groundnut and cotton, are showing substantial increase in their acreage, but the area under sugarcane is not much increasing.

Since there is a limit to increase in area and it may not be possible to maintain the same growth rate in the next 15 years as observed in the recent past, the growth rates in the case of different crops have, by and large, been assumed to decline progressively. Depending upon the nature and importance of crops, however, some variations have been made. Due consideration has also been given to the irrigated areas, and trend in their extension. It is presumed that the potential created by most of the irrigation works, so far undertaken, will be fully utilized by 1978-79. Thus largest addition to irrigated area is expected to take place during the next 10 years.

The area projections for various crops are very rough and could, at the most, be accepted as guidelines, as in this exercise no consideration has been paid to the relative changes that may take place in the prices of different agricultural products over the next 15 years. It seems, however, correct to presume that for the purposes of this study the overall position is a viable one.

On the basis of these projections for the crop areas, the total and monthly requirements of human and animal labor in different years have been computed by multiplying the area under crop with energy inputs and then totalling them up. Adjustment for miscellaneous crops, which have been unaccounted for in the crop projections, have been made in proportion to their area to the total cropped area.