Vol XXXI
No. 4

ISSN 0019-5014

OCTOBER-
DECEMBER
1976

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

IMPACT OF MECHANIZATION ON PUNJAB AGRICULTURE WITH SPECIAL REFERENCE TO TRACTORISATION

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Introduction

The recent technological breakthrough in the Punjab agriculture, which came mostly through the introduction of High-Yielding Varieties and the associated technology, resulted in increasing agricultural productivity per unit area. It accelerated mechanization of irrigation on the bullock operated farms, which increased the intensity of farming. The farmers were then faced with the problem of increasing productivity per unit of time. All these developments paved the way for large-scale introduction of tractors in the Punjab.

This development was criticised by those who hold the popular belief that mechanization leads to large-scale displacement of labour. Others defended this development, by making some 'quickee'-type studies on the impact of mechanization without separating out the effects of irrigation from those of tractorisation. In the process they attributed to tractorisation increments in yield, output, employment, productivity and profitability per hectare, which strictly speaking did not belong to tractorisation. As a result, some of these studies became suspect. Since the World Bank was considering a proposal to advance a big loan to the Government of India for supporting this development in the Punjab, it came up with a proposal to provide financial support for a comprehensive research study on the impact of tractorisation on the Punjab agriculture. The author was commissioned to do this study which forms the basis for this paper.

Major Objectives

The more specific objectives of this study are (*i*) to measure the impact of tractor mechanization on farm labour employment, output and productivity in the representative farming areas of the Punjab, and (*ii*) to examine the private rate of return on tractor investment. The induced non-farm employment created by farm mechanization was not studied because of data limitations regarding off-farm employment in the industries which are engaged in manufacturing, servicing and repairing of tractors and tractor drawn implements and the modern technological inputs associated with the adoption of the new technology.

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METHODS AND MATERIALS

In a study like this, it is important to control as many factors as can possibly be done at the sampling stage. The cropping patterns were controlled by dividing the Punjab into homogeneous zones with respect to cropping patterns. The horse-power of the tractors was controlled by dividing the tractor population into four horse-power categories. An attempt was made to control farm size by selecting comparable farm size-groups of bullock and tractor operated holdings. Since the farm size differences could not be completely controlled at the sampling stage, its effect was removed through co-variance analysis, whenever the differences in the characteristics of the bullock and tractor operated farms came out to be significant.

Wheat being the principal crop in winter throughout the State, the study was located in the specialised crop regions based on the concentration of such *kharif* crops as rice, maize, groundnut and cotton. The first three strata constituted Zone I which formed groundnut, maize and paddy areas. Paddy and maize in the semi-hilly areas formed Zone II, whereas cotton and *bajra* (spiked millet) formed Zone III.

Sampling Design

Three-stage stratified random sampling was used to select blocks, villages and sample bullock and tractor operated holdings. The major objective of this study being the impact of tractorisation, the number of blocks selected from each stratum was proportional to tractor population with a minimum of two blocks from each stratum. Two village clusters were selected from each sample block, again with probability proportional to tractor population.

A comparison of the frequency distribution of the bullock and tractor operated holdings in the sample villages gave a comparable size range of 15-40 acres in the first zone; 15-30 acres in the second zone; and 15-56 acres in the third zone. Thus the small bullock operated holdings and very large tractor operated holdings (which were not many) did not form a part of the sample.

Selection of Tractor Farms

The tractor operated holdings were divided into four groups in such a way that each group had approximately 25 per cent of these holdings and were classified according to the following horse-power groups:

(*a*) Tractors between 14-20 HP.

(*b*) Tractors between 25-30 HP.

(*c*) Tractors between 35-37 HP.

(*d*) Tractors between 45-60 HP.

Two tractor operated holdings of comparable size with the bullock operated holdings were selected from each of the horse-power groups from each sample village cluster. Thus 16 tractor operated holdings from each block, 32 from each stratum and 160 in all were selected for study.

Bullock Operated Holdings

To be able to hold farm size constant, an attempt was made to obtain paired observations, so that for each pair the tractor and the bullock operated holdings had the same, or approximately the same farm size. Finding it difficult to select eight bullock operated holdings, each of which could be paired with the sample tractor operated holdings, the final selection was done independently for the tractor and bullock operated farms.

Modification of the Design

The results of the study for 1972-73 compare the tractor operated holdings with the bullock operated holdings. As mechanization proceeded, it was found that more and more bullock operated holdings were using tractor custom service. And in the absence of adequate spare-parts and servicing facilities, most of the tractor operated holdings maintained at least one pair of bullocks. Keeping in view these developments, the sample holdings were classified in the following four categories (treatments) for 1973-74 analysis.

		No.
(A)	*Bullock operated holdings*	
	(*i*) Pure bullock operated	69
	(*ii*) Bullock plus tractor custom	67
(B)	*Tractor operated holdings*	
	(*i*) Tractor plus bullock operated	99
	(*ii*) Pure tractor operated	37
		272

Within each zone (stratum), the sample falls within the framework of completely randomized design with four treatments, and wherever the zonal data were required to be pooled, randomized block design could be used with 5 blocks (zones) and 4 treatments. Thus we were able to select a design and the ultimate units of study (farms) which were representative of the Punjab in some sense and also allowed efficient tests of the study-hypothesis. The analysis of variance was done, not only for selected characteristics of irrigation,

farm size, but also for output and employment to find the significance of difference between bullock and tractor operated treatments. Since these models contained a mixture of discrete and continuous variables and even all the key variables could not be controlled, the analysis of variance was not repeated for such study variables, where many more variables were involved than can possibly be controlled through an experimental design.

Recognizing that in the experimental designs, bullock and tractor treatments were considered together, the results obtained from such analyses were, strictly speaking, not comparable with separate production functions fitted for the bullock and tractor operated holdings in the regression analysis. It was, therefore, considered appropriate to use one function at the stage of regression analysis by incorporating dummy variables to measure the shift in the production surface.

Major Characteristics of the Sample Farm

There was hardly any difference in the average farm size of pure bullock farms and bullocks with the tractor custom service. However, the difference between pure tractor and tractor with bullock farms seemed to be significant. Whenever the difference in the farm size occurred, its effect was eliminated at the analysis stage, using the co-variance technique. Again there was not much difference in the number of fragments on the bullock and tractor operated holdings because of the consolidation of holdings in the State. The percentage of net sown area was higher on the tractor farms than on the bullock farms and the proportion of current fallows was declining on the tractor farms relative to the bullock operated holdings. Finally, there was hardly any difference in the percentage irrigated area between different treatments which formed 95.40, 97.79, 99.75, 96.53 and 93.67 per cent on the pure bullocks, bullocks with custom service, pure tractor, tractor with bullocks and large tractor farms respectively.

RESULTS AND DISCUSSION

The results of this study need to be reviewed in the special context of the Punjab situation where irrigation is almost as much mechanized on the bullock operated holdings as on the tractor operated holdings. Also, most of the bullock operated holdings used bullock drawn improved farm implements, which have been developed over time; whereas most of the tractor farmers have not as yet developed matching machinery system. In that sense, tractorisation may not have a great edge over bullock operated farmers at least in the early stages of the introduction of tractors.

Intensity of Cropping

One of the hypotheses that the tractor use promoted intensity of cropping was tested. The index of cropping intensity at 177.62 was the highest on

the pure tractor farms compared with 158.65 on the pure bullock farms. However, the correlation coefficients between farm size and intensity of cropping were insignificant in almost all the cropping zones. Again, the correlation coefficients betwen the size of farm and horse-power of the tractors and between horse-power of the tractor and intensity of cropping were not significant in any strata. Also, bivariate frequency distribution of tractor holdings according to farm size and the horse-power of the tractor did not establish any definite relationship between farm size and horse-power of the tractor, using the Chi Square Test.

TABLE I—BIVARIATE FREQUENCY DISTRIBUTION OF TRACTOR HOLDINGS ACCORDING TO FARM SIZE AND HORSE-POWER OF THE TRACTOR

Farm size (hectares)	Horse-power of the tractor				Total
	14-20HP	25-30HP	35-37HP	45-60HP	
6—9	18	16	15	7	56
9—12	4	10	9	5	28
12—15	9	7	13	2	31
15 and above	5	6	4	8	23
Total	36	39	41	22	138
Average farm size	10.58	10.73	10.94	12.00	

Yield Levels of Important Crops

The yields of maize, wheat and paddy local were marginally higher on the tractor farms than that on the bullock farms. To test the significance of the real difference in yields owing to farm size and fertilizers, the analysis of co-variance was applied which showed that these differences in most of the cases were non-significant.

Yields in Rotation

It was hypothesized that tractor cultivation made timely sowing of the crop possible, particularly in a rotational system. The results showed that the yield of wheat after paddy was marginally higher on the tractor farms in strata I and IV, but the difference was again non-significant.

Levels of Inputs and Yields

Fertilizer use was marginally higher on wheat, maize and paddy in the case of tractor farms but no definite relationship could be established between fertilizer use and yield levels. Again, the number of irrigations was marginally higher on the tractor farms, but no definite relationship could be established between the number of irrigations and yield per hectare on the bullock and tractor farms.

Wheat Yields at Higher Cropping Intensity

It was hypothesized that at high levels of cropping intensity, the difference in yield would show up much better on the tractor farms as compared with the bullock farms. As will be seen from Table II, at the higher level of cropping intensity of (*a*) 175-184 and (*b*) 185 and above, tractor yields were significantly higher than the yields obtained on the pure bullock farms.

TABLE II—YIELD OF WHEAT PER HECTARE ACCORDING TO CROPPING INTENSITY

(*quintals*)

Intensity	Pure bullocks	Bullocks with custom service	Pure tractor	Tractor with bullocks
175 to 184	18.97	26.49	27.99	27.44
185 and above ..	23.33	26.75	29.01	26.12

Output and Productivity

Gross output per hectare of the pure bullock farms was the lowest of all farm size-groups and productivity on the pure tractor farms was the highest. The difference was significant in the strata I, II and IV. This was possible because the tractor farms had more acreage under such cash crops as sugarcane and potatoes than the bullock operated farms had.

Farm Business Analysis

As will be seen from Table III, per hectare profit on the pure tractor farms was markedly higher than that of the pure bullock farms, being Rs. 2,672.55 and Rs. 1,866.23 per hectare respectively. Also, the profit on the pure tractor farms was significantly higher than that of the tractor with bullock farms. Thus it can be concluded that tractorisation improved profitability but the maintenance of bullocks along with the tractors resulted in considerable reduction in profits of the tractor plus bullock operated farms.

TABLE III—PROFIT OR LOSS* PER HECTARE FROM VARIOUS CATEGORIES OF BULLOCK AND TRACTOR FARMS: 1973-74

(*Rupees*)

Strata	Pure bullock farms	Bullock farms with custom service	Pure tractor farms	Tractor with bullocks
I	1,542.30	1,438.53	1,851.33	2,032.58
II	2,227.25	3,069.66	4,494.61	2,227.54
III	1,909.18	1,846.22	2,316.92	1,895.54
IV	1,802.69	2,630.28	2,027.31	2,053.04
V	1,849.74	2,619.59	—	2,061.95
Overall	1,866.23	2,320.86	2,672.55	2,054.13

* These figures of profit or loss were worked out by deducting from gross returns variable cost plus depreciation on fixed capital.

Budgets

Using the actual coefficients, budgets were prepared for the bullock and tractor operated farms for (*a*) model size farm of 6-7 hectares,(*b*) ceiling limit size farm of 8-9 hectares, (*c*) average farm size of different categories.

Tables IV, V and VI show that the increment in net returns on the pure tractor farms was Rs. 1,593, Rs. 338 and Rs. 1,026 per hectare on the model size farm of 6-7 hectares, ceiling limit size farm of 8-9 hectares and average farm size respectively.

Cost-Returns Analysis of Different Horse-Power Tractors

It was hypothesized that the cost per hectare per hour had positive association with the size of the tractor and returns had marginally positive association. The study showed that the variable cost of tractor use per hour increased consistently from Rs. 2.86 to Rs. 6.29 as the tractor size increased from 14-20 HP to 45 and above HP. Similarly, the total cost including depreciation per hour increased from Rs. 5.56 to Rs. 12 as the tractor size increased from 14-20 HP to 45 and above HP.

It could be argued that on the large farms there would be higher horse-power tractor and economies of tractor size were influenced by economies of farm size. However, the results showed that there was little correlation between farm size and horse-power of the tractors.

Net returns per hectare were worked out for different horse-power categories. No definite association between tractor size and net returns per hectare could be established but it was noted that by and large the net returns per hectare were greater on 14-20 HP tractor farms than that on the higher horse-power categories.

OUTPUT-INPUT RELATIONSHIP

Production function analysis was done separately for the bullock operated, tractor operated and for all farms pooled together, pooling all the strata. A dummy variable was introduced to study the shift in production function due to tractorisation and determine the shift in the constant term as well as in the coefficients of the independent variables owing to the impact of custom hire service on the bullock operated farms. Similarly, a dummy variable was introduced to bring out the differences in the intercept and the coefficients of the pure tractor farms and tractor plus bullock farms. Whereas the significance of the coefficients of dummy variables in the linear function gave the shifts in the marginal value product of the corresponding variables, the same in the Cobb-Douglas function gave the shifts in the elasticities. There being

TABLE IV—EFFECT OF DIFFERENT DEGREES OF MECHANIZATION ON NET RETURNS
(MODEL FARMS)

(Rupees per hectare)

Items	Pure bullocks	Bullocks with custom service	Increment or decrement	Pure tractor	Increment or decrement		Tractor with bullocks	Increment or decrement		
	(1)	(2)	(2—1)	(3)	(3—1)	(3—2)	(4)	(4—1)	(4—2)	(4—3)
Variable cost ..	1,687·85	2,208·08	520·22	3,285·89	1,598·03	1,077·81	1,873·45	185·59	—334·63	—1,412·44
		(1,863·08)	(175·22)	(3,055·45)	(1,367·59)	(1,192·37)			(10·37)	(—1,182·00)
Total cost ..	2,015·32	2,523·56	508·24	4,140·42	2,125·10	1,616·86	2,774·04	758·72	250·48	—1,366·28
		(2,183·26)	(167·94)	(3,913·15)	(1,897·83)	(1,729·89)			(590·78)	(—1,139·11)
Gross returns ..	4,161·71	5,073·52	911·81	7,880·20	3,718·49	2,806·68	4,928·60	766·89	—144·92	—2,951·60
		(4,321·24)	(159·53)	(6,445·02)	(2,283·31)	(2,123·78)			(607·36)	(—1,516·42)
Net returns ..	2,146·39	2,549·96	403·57	3,739·78	1,593·39	1,189·82	2,154·56	8·17	—395·40	—1,585·22
		(2,134·98)	(11·41)	(2,531·87)	(385·48)	(396·89)			(19·58)	(—377·31)

Note :—Figures in parentheses exclude potato growing holdings.

TABLE V—EFFECT OF DIFFERENT DEGREES OF MECHANIZATION ON 8-9-HECTARE FARMS (CEILING LIMIT)

(Rupees per hectare)

Items	Pure bullocks	Bullocks with custom service	Increment or decrement	Pure tractor	Increment or decrement		Tractor with bullocks	Increment or decrement		
	(1)	(2)	(2—1)	(3)	(3—1)	(3—2)	(4)	(4—1)	(4—2)	(4—3)
Variable cost ..	1,582.64	1,966.50	383.86	2,073.35	490.71	106.85	1,928.09	345.45	—38.41	—145.26
Total cost ..	1,893.52	2,137.11	243.59	3,103.74	1,210.22	966.63	2,725.93	832.41	588.82	—377.81
Gross returns ..	3,511.94	3,918.08	406.14	5,060.25	1,548.31	1,142.17	4,658.78	1,146.84	740.70	—401.47
Net returns ..	1,618.42	1,925.03	306.61	1,956.51	338.09	31.48	1,932.85	314.43	7.82	— 23.66

TABLE VI—EFFECT OF MECHANIZATION ON AVERAGE FARM SIZE

(Rupees per hectare)

Items	Pure bullocks	Bullocks with custom service	Increment or decrement	Pure tractor	Increment or decrement		Tractor with bullocks	Increment or decrement		
	(1)	(2)	(2—1)	(3)	(3—1)	(3—2)	(4)	(4—1)	(4—2)	(4—3)
Variable cost	1,499·31	1,816·67	317·36	2,040·44	541·13	223·77	1,673·10	173·79	—143·57	—365·34
Total cost	1,762·73	2,039·96	273·23	2,827·14	1,064·41	787·18	2,274·17	511·44	234·21	—552·97
Gross returns	3,620·80	4,357·53	736·73	5,711·44	2,090·64	1,353·91	4,288·61	667·81	—68·92	—1,422·83
Net returns	1,858·07	2,317·57	463·50	2,884·30	1,026·23	566·73	2,014·44	156·37	—303·13	—869·86

not much difference in the R^2 values and the standard errors of the regression coefficients, both the functions were fitted to the data.

(1) $Y = b_0 + b_1x_1 + b_2x_2 + \ldots. b_8x_8 + B_0D + B_1DX_1 + B_2DX_2 \ldots + B_8DX_8$

(2) $\log Y = C_0 + C_1 \log X_1 + C_2 \log X_2 + \ldots\ldots C_8 \log X_8 + \gamma_0 D + \gamma_1 D_1 \log X_2 + \ldots. \gamma_8 D_8 \log X_8$

where X_2 = farm size (hectares),
X_3 = tractor labour hours per hectare (corrected for horse-power),
X_4 = bullocks labour hours per hectare,
$X_5 = \frac{(X_3 + X_4)}{2}$ tractor plus bullock labour hours (one pair of bullocks=$\frac{1}{2}$ horse-power),
X_6 = expenditure on yield increasing technology expressed on per hectare basis,
X_7 = human labour hours per hectare,
X_8 = irrigation hours per hectare,
X_9 = dummy variable,
$X_{10} = DX_2$ = dummy for farm size,
$X_{11} = DX_3$ = dummy for tractor labour,
$X_{12} = DX_4$ = dummy for bullock labour,
$X_{13} = DX_5$ = dummy for tractor and bullock labour,
$X_{14} = DX_6$ = dummy for expenditure on yield increasing technology,
$X_{15} = DX_7$ = dummy for human labour,
$X_{16} = DX_8$ = dummy for irrigation.

For $D = 0$, the coefficient b_i gives the marginal value product of variable X_i for the bullock farms. The coefficient B_i is the shift in the MVP of X_i due to tractorisation ($D = 1$ for tractor farms). Similarly, the coefficient C_i represents the elasticity of X_i for the bullock operated farms and the cofficient γ_i gives the shift in the elasticity due to tractorisation.

A careful examination of the correlation matrix showed the presence of multicollinearity when the variables were expressed on a per hectare basis. Therefore, all the variables indicated above could not be included in the production function. Table VII shows those variables which were finally retained in the model. It will be seen from Table VII that the MVPs of human labour at 2.4418 and that of irrigation at 6.8203 were significant at 1 per cent level on the pure bullock farms. Others were non-significant. Custom hire tractor service on the bullock farms did not change significantly the MVPs for human labour and irrigation, but it did result in significantly lowering the MVP of bullock labour from .3468 on the pure bullock farms to —7.2879. Similarly, the elasticities for human labour and irrigation in the case of Cobb-Douglas function were significant at 1 per cent level on the pure bullock farms. The results showed that 1 per cent increase in human

TABLE VII—MVPs AND ELASTICITIES (ALL STRATA POOLED)

	Linear functions			Double log functions		
	B.F.	T.F.	B.F. *vs.* T.	B.F.	T.F.	B.F. *vs.* T.F.
Number of observations	N (136)	N (136)	N (272)	N (136)	B (136)	N (272)
$R^2 \times 100$	68.0221	76.0415	69.1781	65.4535	71.1173	63.3622
Constant term	1496.1993** (448.3480)	1430.9106 (856.9287)	552.7128 (456.3867)	1.9655** (0.2771)	1.4673** (0.3612)	1.6421** (0.2144)
X_2=Farm size	—	—143.3523* (69.0029)	98.3182** (23.5073)	0.0981 (0.0833)	—0.2599* (0.1245)	0.2541** (0.0615)
X_3=Tractor labour hours/ hectare	—	—	—	—	—0.0317 (0.0882)	—
X_4=Bullock labour hours/ hectare	0.3468	—	—	0.0095	—	—
X_5=Tractor plus bullock labour hours/ hectare	—	—	4.3382** (1.0205)	—	—	0.1296** (0.0337)
X_6=Expenditure on yield increasing technology/ hectare	0.0733 (0.7694)	6.4168** (0.8920)	0.9188 (0.3028)	—	0.4944** (0.0783)	0.0973* (0.0415)
X_7=Human labour/hectare	2.4418** (0.9263)	1.5906 (0.8151)	2.6221** (0.5471)	0.3979** (0.1113)	—	0.2916** (0.0806)
X_8=Irrigation hours/hectare	6.8203** (2.2884)	12.8685** (3.4152)	10.8201** (2.0156)	0.1980** (0.0517)	0.4541** (0.1071)	0.2133** (0.0417)
X_9=D=dummy variable	430.7499 (584.5583)	490.3611 (1025.4972)	1658.1829* (677.0196)	—0.2562 (0.4053)	1.2752** (0.4041)	0.6970* (0.2746)
$X_{10}=DX_2$	—	143.3879 (74.2380)	—0.0098 (34.5006)	0.2470* (0.1145)	0.1299 (0.1389)	—0.3436** (0.0866)
$X_{11}=DX_3$	—	—	—	—	0.0850 (0.0924)	—
$X_{12}=DX_4$	—7.6347*	—	—	—0.1583 (0.0677)	—	—
$X_{13}=DX_5$	—	—	—0.0437	—	—	—0.0001 (0.0545)
$X_{14}=DX_6$	1.2359 (1.1096)	—3.4531** (1.1439)	3.8985** (0.8439)	—	—0.2139* (0.0878)	0.2460** (0.0584)
$X_{15}=DX_7$	0.6250 (1.1146)	0.3990 (1·0386)	—0.6735 (0·7566)	0.1778 (0·1484)	—0.3842** (0·1139)	—0.1822* (0·0908)
$X_{16}=DX_8$	—1·5698 (4·0336)	—9·2297** (4·3610)	—2·9948 (3·0187)	—0·0545 (0·0808)	—	—0·1272* (0·0574)

Note :— Standard errors of estimates are given in parentheses.
*indicates significant at 5 per cent probability level.
**indicates significant at 1 per cent probability level.

labour increased output by .40 per cent, whereas 1 per cent increase in irrigation increased output by .20 per cent on the pure bullock farms. Introduction of tractor custom service did not change these elasticities significantly, but it shifted the elasticity of bullock labour from .0095 (non-significant) to —0.158 (negative and significant). Returns to scale elasticity was 1.0981 and not being significantly different from unity, it indicated constant returns to scale.

Tractor Operated Farms

The MVPs for irrigation and expenditure on yield increasing technology were significant on the pure tractor farms, being 12.87 and 6.42 respectively. These were reduced by 9.23 and 3.45 respectively on the tractor with bullock farms. The elasticity coefficient on the pure tractor farms was significant for farm size, expenditure on yield increasing technology and irrigation, the elastisities being— .2599, .4944 and .4541 respectively. But the maintenance of bullocks on the tractor farms brought down these elasticities considerably to render farm size and irrigation hours elasticities non-significant.

All categories pooled (*bullock farms versus tractor farms*)

This was a sample of 136 bullock operated farms and 136 tractor operated farms. The variables included in the function were farm size, bullocks and tractor labour, expenditure on yield increasing technology, human labour and irrigation. *The MVPs of most of the variables were significant and positive on the bullock farms as well as on the tractor farms.* Tractorisation induced a significant increase of 3.90 in the MVP of .92 for expenditure on yield increasing technology. In the case of all other variables the hypothesis of greater MVPs on the tractor farms was rejected.

It was found that tractorisation led to an upward shift of the present function. The constant term for linear function worked out to be 552.71 on the bullock farms which increased by 1,658.18 as a result of tractorisation. In the case of double log function, the intercept increased from 1.6421 on the bullock farms to 2.3391 on the tractor farms. The resultant increase of .6970 was significant at 5 per cent probability level.

It was interesting to note that bullock labour and tractor power combined into a single variable (X_5) gave better results after separate variables for tractor labour hours (X_3) and bullock labour hours (X_4) were dropped from the equations.

EMPLOYMENT OF HUMAN LABOUR

The pattern of employment of human labour per holding showed that family labour was employed more on the pure bullock farms, casual labour was

hired more on the pure tractor farms and permanent labour was employed more on the tractor with bullock farms. Without separating out the effect of other variables on employment, throuh regression analysis, it was found that on a per holding basis, family labour declined by 33 per cent on the tractor farms, casual labour increasd by 6.5 per cent and permanent labour increased by about 21.5 per cent. Total labour employment declined on the tractor farms by 5-6 per cent, but the difference was not significant.

Human Labour Employment on Cropped Hectare Basis

Recognizing that the size of farm could not be completely controlled for different treatments, it becomes more valid to study the employment of human labour on cropped hectare basis. The results conformed to the pattern of employment specified on per holding basis. The analysis of variance showed that the differences were significant for family labour in 1973-74 in all the strata. The differences in casual labour employment were significant in strata II and IV. But for total labour employment, the differences were non-significant in all the strata for 1973-74.

When the pure bullock farms were compared with the pure tractor farms, it was seen that family labour and total labour decreased by 59.53 per cent and 1.08 per cent respectively, whereas permanent and casual labour increased by 26.85 and 71.96 per cent respectively on the tractor farms (1973-74). The trend of labour employment for 1972-73 was about the same, that is, tractorisation reduced the employment of family labour and total labour by 37.74 and 11.46 per cent respectively. But at the same time, it increased employment of permanent labour by 0.52 per cent and of casual labour by 11.32 per cent on per cropped hectare basis.

Employment of Human Labour according to Horse-Power Categories

It was hypothesized that employment of human labour decreased with the increase in the horse-power of the tractor. The inconsistent trends in different strata did not establish any relationship between horse-power category and employment of human labour both on per holding and cropped hectare basis.

Demand Functions for Different Kinds of Human Labour

Assuming simultaneous nature of relations in the employment of family labour, hired labour and permanent labour, the demand function for different kinds of labour was expressed as

$$L_i = f_1 (X_1, X_2, X_3, L_2, L_3, P_1)$$
$$L_2 = f_2 (X_1, X_2, X_3, L_1, L_3, P_2)$$
$$L_3 = f_3 (X_1, X_2, X_3, L_2, L_1, P_3)$$
$$L = L_1, L_2, L_3.$$

where

L_1 = employment of family labour (man-hours per hectare),
L_2 = employment of casual labour per hectare,
L_3 = employment of permanent labour per hectare,
L = employment of total labour man-hours per hectare,
X_1 = farm size (hectares),
X_2 = proportion of irrigated area,
X_3 = expenditure on yield increasing technology per hectare,

P_1, P_2 and P_3 are total wage payments to family, casual and permanent labour. The shifts in the functions due to mechanization were studied by incorporating dummy variables to determine the change in the intercept term as well as in the coefficients of X_1, X_2, X_3.

After incorporating the dummy variables the model takes the form:

$$L_1 = f_1 (A, X_1, X_2, X_3, L_2, L_3, DA, DX_1, DX_2, DX_3, P_1)$$
$$L_2 = f_2 (B, X_1, X_2, X_3, L_1, L_3, DB, DX_1, DX_2, DX_3, P_2)$$
$$L_3 = f_3 (C, X_1, X_2, X_3, L_1, L_2, DC, DX_1, DX_2, DX_3, P_3)$$
$$L = L_1 + L_2 + L_3$$

L_1, L_2 and L_3 are the endogenous variables of the system which were studied through simultaneous interactions of the relations in the model. Both the order and rank conditions were satisfied and hence the equations were exactly identified.

Linear Functions

Bullock versus tractor farms: The study showed that whereas family labour function dropped and the other functions moved upwards for the tractor farms in comparison with the bullock farms, none of the shifts exhibited significance. This is supported by the fact that the intercept of the total labour function changed from 438.34 man-hours per hectare on the bullock farms to 679.35 man-hours on the tractor farms, the change remaining insignificant.

Cobb-Douglas Function

As will be seen from Table VIII, the elasticity coefficients improved slightly on the tractor farms by 0.1470, 0.0676 and 0.2230 for L_1, L_2, and L_3, respectively, of which 0.1470 was significantly different from zero. The results showed that on the whole, tractorisation did not result in any significant shift in the labour functions, particularly those relating to L_2 and L_3 types of labour. What little shifts were observed, they occurred in respect of family labour (L_1). In this case the intercept decreased from 0.1723 to —.07725, which was significant at a probability level of 5 per cent. The total labour input (when all the exogenous variables were held at their geometric mean

TABLE VIII—ESTIMATES OF ELASTICITIES

	Bullock versus tractor farms (all farms pooled)			Bullock versus bullock + custom hire service farms			Tractor versus tractor + bullock farms		
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
R^2(%)	99·59	89·63	98·26	99·12	89·47	98·33	99·89	90·92	97·98
Constant term	·1723	0·2548	·07002	·04959	·004733	—·07021	·1292	·006689	—·02492
X_1	—1·132*	—·9023*	—·9826*	—1·0816*	—·7218*	—·8210	—·9975*	—·9080*	—1·0878*
	(0·0143)	(0·0531)	(0·1196)	(0·0291)	(0·0823)	(0·02001)	(0·0196)	(0·1401)	(0·2571)
X_2	·09980*	·2059	·06118	·04710	·1465	·5660	·002663	·8022	·01281
	(0·0461)	(0·1873)	(0·3684)	(0·0696)	(0·2204)	(0·4776)	(0·1677)	(1·192)	(2·1887)
X_3	·01452	·08859*	—·01381	·01997	·04818	—·007855	·0008499	·2287*	·05110
	(0·00878)	(0·0349)	(0·0700)	(0·0141)	(0·0444)	(0·0970)	(0·00939)	(0·0629)	(0·1225)
P_1	1·000*	—	—	1·0020*	—	—	·9974*	—	—
	(0·00490)			(0·0122)			(0·00341)		
P_2	—	·8525*	—	—	·8887*	—	—	·8310*	—
		(0·0279)			(0·0433)			(0·0371)	
P_3	—	—	·9420*	—	—	·9369*	—	—	·9527*
	—	—	(0·00914)			(0·0138)			(0·0137)
L_1	—	·004307	—·3703	—	·02199	—·04091	—	—·01290	—·04694
		(0·0204)	(0·0397)		(0·0392)	(0·0832)		(0·0241)	(0·0445)
L_2	·01295	—	·01690	·03803*	—	·02773	·00003235	—	·01749
	(0·00804)		(0·0640)	(0·0155)		(0·1049)	(0·00628)		(0·0819)
L_3	—·002734	—·006791	—	—·004142	·0005512	—	—·0005486	—·01474	—
	(0·00121)	(0·00494)		(0·00212)	(0·00685)		(0·00110)	(0·00778)	
D	—·07725*	—·2502	·3440	·1112	·1561	·2596	—·0124	·2011	—·2700
	(0·0386)	(0·1571)	(0·3085)	(0·0669)	(0·2148)	(0·4593)	(0·0367)	(0·2592)	(0·4782)
DX_1	·1470*	·06767	·2230	—·04818	—·3095*	—·1583	·005213	·05566	·3532
	(0·0190)	(0·0777)	(0·1522)	(0·0335)	(0·1076)	(0·02297)	(0·0221)	(0·1573)	(0·2574)
DX_2	—·09946	—·3581	—·4450	·1215	·04559	—·3846	—·01294	—·8930	—·4001
	(0·0624)	(0·2536)	(0·4988)	(0·1390)	(0·4436)	(0·9541)	(0·1695)	(1·205)	(2·211)
DX_3	—·02013	·07108	·04439	—·02964	·05861	—·03464	—·002223	—·08962	—·000023
	(0·0122)	(0·0495)	(0·0971)	(0·0220)	(0·0695)	(0·1506)	(0·0105)	(0·0746)	(0·1375)

The standard errors of the regression coefficients are shown in parentheses.

levels) showed a very small jump on the tractor farms in relation to the bullock farms. In fact, from a level of 504.97 man-hours per hectare on the bullock farms, the total labour moved up only to 512.12 on the tractor farms, a change of only 7.15 man-hours per hectare.

EMPLOYMENT OF BULLOCK LABOUR

It was hypothesized that bullock labour use declined with tractorisation. Employment of bullock labour was studied both on per holding and per hectare basis.

It will be seen from Table IX that per holding bullock labour use was as high as 1,185.71 hours on the pure bullock operated farms, but it was reduced to 833.16 hours on the bullock farms which used tractor custom service and to as low as 441.26 hours on the tractor with bullock farms. Again, per hectare bullock labour use worked out to be 75.45, 58.42 and 23.94 bullock-pair hours on the pure bullock farms, bullock with tractor custom service and tractor with bullock farms. Thus bullock labour use came to about one-third on the tractor with bullock farms as compared to the pure bullock farms.

TABLE IX—BULLOCK LABOUR EMPLOYMENT IN HOURS WITH TRACTOR DRAWN SEED DRILL

Strata	Pure bullock farms		Bullock with custom farms		Tractor with bullock		Tractor large farms	
	Per holding	Per cropped hectare	Per holding	Per cropped hectare	Per holding	Per cropped hectare	Per hectare	Per cropped hectare
I	1,659·58	113·31	1,262·37	90·86	424·46	22·04	272·50	7·73
II	525·57	39·74	432·74	33·68	188·00	9·84	4·40	0·13
III	1,085·87	69·78	745·00	55·03	527·63	27·58	529·21	14·11
IV	1,086·44	82·79	787·70	65·30	267·50	16·63	197·82	7·74
V	1,316·23	64·61	1,022·80	55·90	592·75	29·70	875·50	18·90
Overall 1973-74	1,185·71	75·45	833·16	58·42	431·12	23·94	389·84	11·12
1972-73	1,187·02	83·69	—	—	441·26	25·01	—	—

POLICY IMPLICATIONS

1. The profitability of the tractor farms could be increased

   (*i*) By tailoring the tractor horse-power to the size of farm. This can best be done by manufacturing four-wheel small tractors of about 14-20 HP.

   (*ii*) By providing an adequate infrastructure and suitable maintenance, servicing and repairing facilities for farm machinery.

   (*iii*) By expanding tractor use on the farm and cutting down its use for social functions.

(*iv*) By developing short duration photo insensitive varieties which would help increase cropping intensity through timely sowings by the tractors.

(*v*) By eliminating bullocks on the tractor farms. So long as the bullocks are maintained on the tractor farms, there is limited scope of increasing profitability from farm mechanization.

2. Both the large and the small farms would be benefited by expanding the tractor custom service.

3. There was no danger of displacement of human labour on tractor farms so long as cropping intensity could be enhanced and such operations as harvesting and threshing by harvester combine were not introduced on a large-scale.