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MECHANISED LAND TILLAGE AND LABOUR EMPLOYMENT IN CROP PRODUCTION ACTIVITIES IN BANGLADESH

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ABSTRACT

This study was undertaken to examine empirically the extent of labour displacement crop-wise due to mechanised land tillage and its impact on land productivity using the recent farm level data covering major agricultural regions of Bangladesh. Machine power used farms were more cost effective in production activities than animal power used farms. Estimated per cropped hectare return was Tk. 11190 for machine power used farms (168% higher than bullock operated farms) and Tk. 6659 for animal power operated farms. Cropping intensity and adoption of seed-fertilizer-irrigation technology were higher for machine power used farms than animal operated farms. Per hectare net gain for using machine power (through yield increase) has been Tk. 2121 and loss of labour income due to displacement of labourer has been Tk. 971 yielding a positive net gain of Tk. 1151 per hectare in terms of social gain in using machine power in land tillage. This supports the view of encouraging uses of machine power in land preparation as much as possible through policy measures.

1. INTRODUCTION

The question of mechanisation in tilling operations needs thorough investigation to assess whether mechanisation of tillage operations help boost productivity and whether there is any conflict between mechanisation and employment of labour in crop productions. This study thoroughly investigated on the impact of mechanisation (land tilling) on production, productivities and consequent changes in labour employment, if any.

Various previous studies on the topic gave a confused state of the affair regarding question of the adoption of tillers in farm operations in our socio-economic context. But with the passing of time, the demand for engine power in tilling operations has been increasing owing mainly to slowness and shortage of human/animal labour in agriculture.

Whether there is any need of farm mechanisation in an apparently labour surplus agriculture has been the daunting question during the last three decades after independence. But at the same token almost everyone has agreed about the shortage of draught power in Bangladesh agriculture. Some reported about peak seasonal labour shortages (Sarker, 1997. p.1). In a study of 'Tractorisation and Rural Employment in Bangladesh', Gill (1982) observed that under farmers field conditions there were no significant differences in yields comparing the tiller operated and draft power used lands.

Asaduzzaman (1988) assessed socioeconomic impact of agricultural mechanisation in Bangladesh. He observed that there had been no land consolidation among the adopters of

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mechanisation though cropping intensity has been higher and there was little yield differentials between mechanised plots and non-mechanised plots.

In a review article, Chowdhury (1991) reported that use of tractors and power tillers were significantly less expensive than tilling with draft animals. As regards the intensity of cropping and yields per acre, mechanical power was not found to be superior to draft animals.

He reported that in the Barind Tract mechanisation increased cropping intensity and made possible introduction of new crops.

In a recent study, Barton (2000) reported that PTs (power tillers) have little impact on rice yields which are more closely associated with choice of variety and fertilizer use. He observed that the introduction of PTs provided employment opportunities for labourers (wage) despite the fact that it reduces the human labour required for land preparation. PT farms use twice as much hired labour than family labour.

In a participatory research appraisal (PRA) report Islam and Sarker (2000) observed that non-farm employment opportunities have increased (reasons not delineated) and the real wage rates of landless labourers have increased in recent years suggesting that there is greater demand or competition for their services. The study has also revealed that sharecroppers are not being affected adversely by the introduction of PTs. So, in the context of such a public debate over the last three decades this piece of research endeavoured to verify a few of these contradictions empirically.

After this introductory section methodology of the study is presented in section 2. Results are presented in different sub-headings in section 3. Last section contains a brief summary and policy recommendations.

II. METHODOLOGY OF THE STUDY

On measuring the extent of labour use efficiency per unit of land area (hectare) for the major crops the present study used the labour productivity approach. This is to fit agricultural production function using a Cobb-Douglas (CD) type production function investigating the marginal productivity of labour to declare, whether surplus labour existed or not. By this marginal productivity approach, if the value of marginal productivity of labour becomes significantly greater than the factor cost (wage rate), it would imply shortage of labour (too little use) for the farm size and crop of concern. Surplus labour would exist if the marginal productivity of labour is observed below the wage rate (over use of labour input). If the value of marginal productivity tends to equal the wage rate would imply that labour input has been efficiently used.

Specification of the Cobb-Douglas Production Function

The production function for farm i, in a sample of 'n' farms is specified as:

(1) $Y_i = A_i \pi X^{\alpha j} e^{Ui}$; $i = 1, \ldots\ldots\ldots\ldots$, n observations

$j = 1, \ldots\ldots\ldots$, kth inputs

u_i = signifies residual errors

α_j = input coefficients

Where Y_i is a measure of output per hectare in value term of the i'th observation, A_i, intercept term is a technical efficiency parameter, $X_{j's}$ are measure of inputs in physical or in value terms per hectare and e^{Ui} is stochastic term incorporating the effects of unknown variables, if any, and errors in measurement. 'j'th input variables would be labour used per hectare, quantity of Urea used per hectare, quantity of TSP per hectare, quantity of MP per hectare expressed together (all fertilizers and insecticides) in value terms per hectare and a dummy variable for irrigation facility adopted or not (user 1, 0 otherwise). Some farmers use irrigation and some farmers do not, therefore, use of dummy variable is imperative rather than using per hectare irrigation cost as explanatory variable[1]. A second dummy variable has been used for power tiller (if use 1, 0 otherwise), to assess the impacts of these on tiller operated and bullock operated farms.

Taking natural logarithm of both sides of equation (1) the estimational equations by following Cobb-Douglas model, would be as follows:

i) $\text{Ln } Y_i = \text{Ln } A + \alpha_1 \text{ Lnprehar} + \alpha_2 \text{ Lnculcos} + \alpha_3 \text{ Lncfi} + \alpha_4 \text{IRDUM} + \text{Ui}$

For comparison sake, four equations; one for tiller used farms, one for bullock operated farms, one pooled equation combining both (groups and the pooled equation with a power tiller dummy) were estimated.

Prefix 'Ln' signify the variable expressed in natural logarithmic term.

prehar = Number of pre-harvest labour used per hectare in man-days for the crop concerned

culcos = Land cultivation cost expressed in Tk. per hectare (either tiller used cost or bullock power used cost).

cfi = cost of fertilizers, manures and insecticides per hectare.

(lumped together, mainly to avoid intercorrelations among these inputs and the influence of individual inputs is not called for in this study)

IRDUM = Irrigation dummy (if used 1, 0 otherwise) and in one pooled equation power tiller dummy (if used 1,0 otherwise).

Land as a variable will not be directly used in the estimation of production function because all are measured on the basis of per hectare of land. That is, dependent variable will be value productivity (output times prices) per hectare.

The Ordinary Least Squares (OLS) technique was used with usual classical assumptions held (Johnston 1972 pp. 122-23). Present day crop production activities have changing rapidly in terms of adoption of modern factor inputs (seed, fertilizer, irrigation and improved management) and these inputs have direct as well as multiplicative cross effects are to capture all of additive and multiplicative effects of components of technology package,

[1] Per hectare cost of irrigation has been used in case of Boro HYV where all the farmers used irrigation (all such farms were tiller operated farms).

estimation of a Transcendental Logarithmic production function method was also computed to have a comparative views of results in relation to CD function.

Estimation of Transcendental Logarithmic ('translog' production function) with the stated variables would be as follows:

$LnY_{ij} = LnA_{ij} + \alpha_{1ij}$ Lnprehar $+ \alpha_{2ij}$ Lnculcos $+ \alpha_{3ij}$ Lncfi $+ \frac{1}{2}\alpha_{11ij}$ $(\text{Lnprehar})^2 + \frac{1}{2}\alpha_{22ij}$ $(\text{Lnculcos})^2 + \frac{1}{2}\alpha_{33ij}$ $(\text{Lncfi})^2 + \alpha_{12ij}$ LnpreharLnculcos $+ \alpha_{13ij}$ Lnprehar Lncfi $+ \alpha_{23ij}$ LnculcosLncfi $+ \alpha_{4ij}$ IRDUM $+ U_{ij}$.

For test of equality of both intercept and slope coefficients across power tiller and bullock operated farms, (to assess the variation in technical efficiency) the null hypothesis tested were:

1. H_o: $bi_T = bi_B$, $i = 0, 1, \ldots\ldots, K$ i.e., the set of coefficients obtained from power tiller (representing mechanised farm) and bullock operated farms are equal in terms of technical efficiency and inputs used (meaning, mechanisation in terms of tiller use has no impact). The test statistic for this would be the Chow-test (1962). That is;

$$F = \frac{[(\Sigma u^2 p) - (\Sigma u^2_T + \Sigma u^2_B)]/K}{(\Sigma u^2_T + \Sigma u^2_B)/(N - 2K)}$$

where,

$\Sigma u^2 p$ = residual sum of squares from the pooled regression.

Σu^2_T, Σu^2_B = residual sum of squares from the regression for tiller operated farms and bullock operated farms respectively.

K = number of estimated parameters in the regression.

N = number of observations in the pooled sample

2. Test of equality of intercept coefficients (assuming common slope coefficients) of the tiller and bullock operated farms (measuring equality of base technical efficiency of production). The null hypothesis in this case would be;

H_0: $\alpha_{0T} = \alpha_{0B}$. The test statistic (meaning there is no difference between tiller operated and bullock operated farms in terms of initial productivity level) is as follows:

$$F = \frac{[(\Sigma u^2_{WD}) - \Sigma u^2_W)/(S-1)}{(\Sigma u^2_W)/\{N - (S + K-1)\}}$$ where,

Σu^2_{WD} = residual sum of squares of regression without power tiller dummy

Σu^2_W = residual sum of squares of regression with power tiller dummy

N = number of observations in the pooled data.

S = number of sampling sources (groups).

K = number of parameters estimated in the pooled regression.

3. Test of common slope coefficients across tiller and bullock operated farms (to see whether resource use efficiency is different or not having same technological base of production)

The null hypothesis in this case is given by

Ho : $\beta j_T = \beta j_B$. ; $j = 1, \ldots\ldots$, K variables, For test statistic

$$F = \frac{[(\Sigma u^2_W) - (\Sigma u^2_T + \Sigma u^2_B)] / (K-1)}{(\Sigma u^2_T + \Sigma u^2_B) / (N - 2K)}, \quad \text{where,}$$

Σu^2_W = residual sum of squares of regression with power tiller dummy

Σu^2_T, Σu^2_B, N, K same as defined before.

Direct Estimation of Labour Demand Function

To see the labour demand functions by operations/activities both in tiller operated and animal power operated (both in irrigated and non-irrigated farms; detail theorisation has been omitted here) forms the four labour demand functions which were estimated (by using the OLS technique) to see the factors influencing farm labour demand:

1. $Lade_{ij} = a_0 + a_{1j}$ Fala $+ a_{2j}$ Laop $+ a_{3j}$ Wage $+ a_{4j}$ Irdum $+ u_i$; i = 1, ----------, n observation; j = respective farm group, i. e., bullock or tiller operated.

This equation was estimated for tiller operated, bullock operated farms respectively. A pooled regression function was run and in addition another pooled regression with PT dummy was also run.

Where Lade = Total labour man-days used per hectare (labour demand) of crop of concern. This can be seen for both pre-harvest and post harvest total labour demand.

Fala = Family labour supplied per farm activity in man-days for the crop of concern.

Laop = land area under cultivation/operation of the crop concern.

Wage = daily average wage rate (in Tk.) prevailing during the crop production season.

Irdum = Irrigation dummy where irrigated farm = 1, 0 otherwise. Dummy for power tiller where power tiller was used is 1 and 0 otherwise. This dummy variable is used to see the total variation in labour demand if any, between bullock operated and tiller operated (mechanised) farms.

U_i = Error term.

Test of variations in mean inputs use between machine power used and animal power used farms if any, between the two contrasting groups was also tested by using a comparative method, i. e. T-test.

Selection of sampling Areas

Selection of areas was purposive to capture the influence of agril. labour supply situation owing to the adoption of farm mechanisation, for example:

i) One area from densely populated region of Comilla (Chandina upazila) with intensive agricultural activities having mechanisation adopted by the farmers was chosen,

ii) One area from moderately populated region from Rajshahi (Tanore upazila) having also mechanisation adopted by the farmers,

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iii) Khoksha upazila from Kustia district a relatively thinly populated region having mechanisation in vogue; and

iv) One flood plain (Active Brahmaputra- Jamuna Flood plain) area from Sirajgonj (Kamarkhand upazila), two additional regions covering central (Dhaka region) and southern Bangladesh (Patuakhali) have also been chosen to give the sample representation of major agroecological regions of Bangladesh. Gazipur upazila, Ghatail and Mirjagonj upazilas were chosen to cover central region of Bangladesh.

From each area 100 farm households (50, 30 and 20 for each size group of small medium and large farms, that is stratification based on farm size) have been chosen. Total sample size finally retained after scruitiny were 696 farm households. Samples were drawn from 88 villages of 10 upazilas covering 8 districts. Data reference period is 1999/2000 fiscal year. Simple random sampling were followed for drawing samples from each stratum of the sampling frame based on farm size (thus the sampling technique became stratified simple random sampling). Of total 696 selected farms, 55 per cent were small (upto 1 hectare of operated area), 34 per cent were medium (above 1 hectare upto 3 hectares of operated area) and 11 per cent were large farms (more than 3 hectares of land). Of total sample units, tiller used farms were 40 per cent, draft power 29 per cent and using both sources of power (machine and animal) were 13 per cent.

Data collection for each crop (transplanted Aman HYV, Boro HYV, Aus HYV, wheat, jute and potato) were completed just after harvesting of each crop.

III. RESULTS AND DISCUSSION

Differences in socioeconomic characteristics of the selected households

Average family size is larger for the machine power used farms than the draft power used farmers but there is no significant difference in average land holdings between the groups (Table 1). There is difference in the average number of working people between the two groups of (machine power used and the draft power used) farm households.

Average education level index (computational procedure is discussed at the Table 1 footnote) was significantly higher for machine power used farms than the bullock operated farms. Farm group using both sources of power also significantly had higher educational index than bullock operator farms. Higher education level of the machine power used farms influenced the adoption of machine power use.

Machine Power use and Labour Demand in Crop Production Activities

Total requirement of human labour might be reduced owing to use of machine power. That can easily be observed with the results of functional relationships provided in Tables 2-4.

Total labour demand for crop production activities is mainly influenced by the area under the crop, going wage rate, family agricultural labour heads and use of whether machine power or animal power used in land preparations and post harvest operations. Labour wage rate as theoretically expected, in general, has significant negative influence on total labour use, which has been observed for Aman HYV, Aus HYV and wheat for tiller operated farms (Table 2). Potato farmers using either of the power sources increases total labour use even if wage rate goes high. According to theory of demand though this seems a perverse relationship but may not be incomprehensible in the face of intense competition when within a given short time period lands of potato crops have to be prepared and intercultural operations have to be completed. During increasing trend of labour wage rate (for shorter land preparation period), anticipating further wage increase, cultivating farmers may rush for more labour hiring reflecting a positively sloped demand curve for a specific crop and for a limited growing season.

Total labour demand would increase with increasing area under the crops and this should be true for all crops and the results emerged accordingly whether this is total labour man-days for all farm operations or if seen as pre-harvest labour demand or only total labour demand for post-harvest operations. Ten per cent increase in area of Boro HYV, Aman HYV, Aus HYV and potato would increase total labour man-days employment by 9.4 per cent, 9.2 per cent, 8.7 per cent and 7.1 per cent respectively.

Table 1 : T-test for socioeconomic characteristics of selected households

Socioeconomic Characteristics	Tiller used farms(a) Mean	Bullock used farms(b) Mean	Both (c) Mean	t-value between		
				(a-b)	(b-c)	(a-c)
Average farm size (ha)	1.27	1.19	1.38	0.65	-1.59	-1.06
Average family size (number)	6.91	6.41	7.62	1.77[c]	-4.08[hs]	-2.25[s]
Total family worker (number)	2.50	2.31	2.81	1.37	-3.81[hs]	-2.17[s]
Average education level index**	10.11	9.74	9.94	3.24[hs]	-1.84[c]	1.47

Note: hs – signify highly significant at 1 percent error level on a two tail test

s - signify significant at 5 percent error level on a two tail test

c – critically significant at 10 percent error level

**Average education level of a family is expressed through using an index where from six to ten was assigned a value of 9, SSC pass was assigned a value of 10 (if not pass 9), HSC pass 12 (if not pass 10), degree to masters pass 14 (if not pass 12) for a family member attaining the education and averaged over the number of assigning members.

Tiller operated farmers (represented by dummy variable) significantly used fewer total labour man-days for Aman HYV, Boro HYV, Aus HYV and for jute. For wheat and potato, the difference in use of total man-days between tiller operated farms and animal power used farms were insignificant. So, use of machine power not displaces human labour equally for all crops.

The effect of pre-harvest labour demand owing to use of tillers in land preparation can be seen with the results presented in Table 3. Tiller used farms required fewer man-days (pre-harvest total labour man-days) for all the crops studied as the negative co-efficients of the dummay variable reveal. All the co-efficients of dummy variables were significant (with negative sign) except potato (negative sign signify lesser use of man-days though). This econometric exercise empirically proves displacement of pre-harvest labour use for the important crops like Aman HYV, Boro HYV, Aus HYV, wheat and jute.

Table 2 : Total labour demand for different crops

(Pooled with dummy variable, for tiller operated farms=1, animal operated farms =0)
(Dependent variable : Total labour man-days employed: all variables in natural logarithm except dummy variable)

Crops	Independent Variable							
	Constant	LnWage	LnFlab	LnOpland	Dummy	R^2	F-ratio	N
Aman(HYV)	6.72 (21.34) hs	-0.41 (-5.37) hs	-0.03 (-1.48)	0.92 (70.00) hs	-0.05 (-2.39) hs	0.94	1459.06	384
Boro(HYV)	5.04 (79.04) hs	0.001 (1.27)	0.02 (1.47)	0.94 (101.58) hs	-0.04 (-2.69) hs	0.95	2592.67	526
Aus(HYV)	5.33 (11.21) hs	-0.13 (-4.18) hs	-0.03 (-1.20)	0.87 (42.47) hs	-0.13 (-4.18) hs	0.90	478.31	221
Wheat	5.83 (14.14) hs	-0.49 (-4.70) hs	0.06 (1.37)	0.57 (18.78) hs	0.01 (0.34)	0.64	92.08	210
Potato	3.85 (7.78) hs	0.25 (2.13) s	0.14 (3.09) hs	0.71 (30.39) hs	-0.004 (-0.08)	0.90	453.68	209
Jute	5.77 (7.62) hs	-0.27 (-1.44)	0.11 (1.78) c	0.63 (20.19) hs	-0.18 (-3.11) hs	0.76	124.57	161

* Total labour including land preparation, transplanting, weeding, application of fertilizer and insecticides, irrigation, harvesting, threshing by ox and machine, crop drying.

** Flab(family labour) including total agricultural own labour (male and female) and 40 per cent of subsidiary labour (male and female)

*** Opland (operated land) hectare of land used in crop cultivation

Impact of use of power tillers on harvest and post-harvest labour use for the crops under study could be seen with the regression results in Table 4 where such labour man-days used were rather higher for Aman HYV, Boro HYV and potato. Such trends have also been observed in an earlier study (Ahmed 1992). This is not implausible while there had been significant yield increase and adoption of modern technologies for these crops.

Statistical test of means of labour used per hectare between machine power and animal power used farms

Test results are presented in Table 5. T-test (mean difference test) of means of total labour use revealed that there has been significant differences in total labour man-days use as a result of machine power use for the crops of Aman HYV, Boro HYV, Aus HYV, and potato implying significantly reduced use of labour man-days for these crops. There has been no significant differences of labour use for wheat (econometric results also revealed such a situation for wheat and potato) and jute. The obvious and similar results were obtained for rice in both econometric and statistical tests.

Rice is an overwhelming crop and labour man-days used show significant reductions in every case (either using machine power fully or partially) which has a greater welfare implications for our farming society.

Table 3 : Pre-harvest labour demand for different crops

(Pooled with dummy variable, for tiller operated farms=1, animal operated farms =0)
(Dependent variable: Total pre-harvest man-days employed: all variables in natural logarithm except dummy variable)

Crops	Independent Variable							
	Constant	LnWage	LnFlab	LnOpland	Dummy	R^2	F-ratio	N
Aman(HYV)	6.81 (20.43)hs	-0.31 (-3.86)hs	-0.08 (-3.12)hs	-0.94 (59.41)hs	-0.10 (-3.70)hs	0.91	1082.66	387
Boro(HYV)	6.49 (9.04)hs	-0.47 (-2.72)hs	-0.13 (-2.33)s	0.55 (15.81)hs	-0.15 (-2.28)s	0.35	69.52	521
Aus(HYV)	5.37 (12.68)hs	-0.19 (-1.81)	-0.05 (-1.16)	0.91 (35.10)hs	-0.21 (-5.09)hs	0.85	331.21	255
Wheat	4.42 (4.72)hs	-0.43 (-1.88)c	0.17 (2.18)s	0.31 (6.57)hs	-0.31 (-3.64)hs	0.23	14.81	198
Potato	1.92 (3.13)hs	0.61 (4.24)hs	0.07 (1.32)	0.68 (23.92)hs	-0.07 (-1.09)	0.87	347.19	208
Jute	5.49 (6.91)hs	-0.36 (-1.94)c	0.08 (1.40)	0.66 (18.98)hs	-0.18 (-3.14)hs	0.71	114.93	189

* Flab (family labour) including total agricultural own labour (male and female) and 40 per cent of subsidiary labour (male and female) involved in agriculture
** Opland (operated land) land used in crop cultivation

Table 4 : Harvest and Post-harvest labour demand for different crops

(Pooled with dummy variable, for tiller operated farms=1, animal operated farms =0)
(Dependent variable : Total Harvest and Post-harvest man-days employed: all variables in natural logarithm except dummy variable)

Crops	Independent Variable							
	Constant	LnWage	LnFlab	LnOpland	Dummy	R^2	F-ratio	N
Aman (HYV)	6.15 (16.53)hs	-0.54 (-5.97)hs	0.05 (1.64)	0.90 (54.81)hs	0.06 (2.11)s	0.90	870.49	379
Boro (HYV)	3.81 (12.50)hs	0.07 (0.93)	0.007 (0.38)	0.93 (67.98)hs	0.05 (1.89)c	0.90	1226.24	521
Aus (HYV)	4.79 (8.40)hs	-0.23 (-1.63)	0.03 (0.68)	0.80 (30.51)hs	0.03 (0.70)	0.82	250.86	214
Wheat	2.56 (4.31)hs	0.24 (1.63)	0.009 (0.24)	0.67 (24.78)hs	0.06 (1.40)	0.79	199.95	206
Potato	5.05 (17.27)hs	-0.33 (-4.44)hs	0.18 (3.61)hs	0.76 (35.26)hs	0.17 (2.62)s	0.87	349.15	205
Jute	5.43 (4.13)hs	-0.26 (-0.83)	0.17 (2.31)s	0.93 (21.04)hs	0.005 (0.07)	0.73	129.09	189

* Post-harvest labour including harvesting, threshing by ox and machine, crop drying and winnowing.
** Flab (family labour) including total agricultural own labour (male and female) and 40 per cent of subsidiary labour (male and female) involved in crop production activities
*** Opland (operated land), total land used in crop cultivation by the sample farm

Table 5 : Comparison of means of labour between the machine (fully or partially) and bullock used farms for different crops (N= 696)

Variable	Aman(HYV)			Boro(HYV)		
	Tiller used farms N=307	Bullock used farms N=194	t-value	Tiller used farms N=425	Bullock used farms N=211	t-value
	Mean	Mean		Mean	Mean	
Labour (ha)	154	170	-4.19^{hs}	173	180	-2.21^{s}
	Aus(HYV)			Wheat		
	Tiller used farms N=143	Bullock used farms N=140	t-value	Tiller used farms N=110	Bullock used farms N=96	t-value
	Mean	Mean		Mean	Mean	
	144	168	-5.04^{hs}	117	107	1.04
	Potato			Jute		
Labour (ha)	Tiller used farms N=162	Bullock used farms N=61	t-value	Tiller used farms N=60	Bullock used farms N=104	t-value
	Mean	Mean		Mean	Mean	
	254	315	-3.37^{hs}	225	238	-0.86

Note: Positive t value means tiller operated farms used more labour than the bullock operated farms

Per hectare cost and return from different crops

Net return per hectare (gross return - total costs) was estimated for the crops under study for two groups of farmers to look into real gains, if any, of using/changing power sources in farm production activities (Table 6). For comparison between two groups for a year, prevailing market prices of inputs and outputs as paid or received by the farmers were taken into consideration for estimating cost or valuing outputs[2].

In terms of net returns by crops, per hectare return received was higher for Boro HYV, wheat and potato for machine power using farms and on the contrary, return per hectare was higher for Aman HYV, Aus HYV and jute for animal power used farms. When per cropped hectare return from all these (in a year) crops grown in a year was estimated, the total per hectare return (Tk. 11190.02) was higher for machine power used farms (68% higher) than bullock power used farms (Tk. 6658.85/ha). So, total return from the crops under study per hectare was distinctively higher in machine power used farms than the animal power used

[2] In farm management studies, estimating full cost of production (economic cost), opportunity cost of land use (calculating interest on capital value of land or value of yearly cash renting), interest on operating capital and value of depreciations of farm equipment and tools were often included. Ideally, as an exercise of economic theory, this is fine but without the existence of perfectly competitive markets for all the inputs, outputs and resources including land, this has little practical relevance and matters little in farmers decisions making in farm production activities. Many hypothesize that farmers are mostly constrained and concerned with paid out/cash costs in decision making process. We, in this study took account of all cash costs/paid-out costs and value of home-supplied inputs and services in estimating cost of productions. We included, home supplied inputs (material inputs and labour), because these immediately can be transacted in the markets if farmers wished/desired.

farms. In terms of total value addition per hectare, machine power used farms were clearly efficient.

Cropping intensity

Farmers using more of modern irrigation facilities and machine power for land preparation should have more cropping frequency in their lands. Table 7 reveals that tiller used farms had cropping intensity of 217 per cent during 1999/2000 period followed by the farms using both sources of power (212%) and the least cropping intensity was observed for the farms using only bullock power user farms for land preparation (182%). It appeared that bullock power user farms represent traditional mode of production activities and lesser user of other modern factor inputs (Table 8) which contributed lower value addition per cropped hectare by them.

Table 6 : Per hectare cost and return of different crops

Crops	Cultivated by machine					Cultivated by animal				
Table	Production (Kg)	Price per kg	Gross Return (a)	Total cost (b)	Net return (a-b)	Production (Kg)	Price per kg	Gross Return (a)	Total cost (b)	Net return (a-b)
Aman HYV	3240	7.46	24170.40	14,973.61	9197.0	3182	7.46	23737.72	14,279.21	9,458.51
Boro HYV	4923	6.93	34116.39	20,429.10	13,687.29	4898	6.93	33943.14	21,059.80	12,883.34
Aus HYV	2470	7.19	17759.30	14,912.66	2846.64	2760	7.19	19844.40	16,206.40	3638.00
Wheat	2081	8.29	17251.49	10,814.84	6,436.65	1990	8.29	16497.10	13,248.34	3248.76
Potato	12880	5.81	74832.80	40,525.50	34307.30	9070	5.81	52696.70	44,308.89	8387.81
Jute	1800	8.7	15660.0	14,994.79	665.21	2110	8.7	18357.0	16,020.30	2,336.70
	Per hectare (cropped) net return				11190.02	**Per hectare (cropped) net return**				6658.85

Total costs include all paid-out costs and imputed value of all home supplied inputs including human and animal labour.

Table 7 : Land use pattern and cropping intensity (%) by power sources of farms

Farmers by power source	Number of farms	Average net cropped area (ha)	Average single cropped area (ha)	Average double cropped area (ha)	Average triple cropped area (ha)	Average four cropped area (ha)	Average total cropped area (ha)	Cropping intensity in 1999/2000
Tiller used farms	279	1.20	0.14	1.62	0.47	0.39	2.62	217
Draft used farms	201	1.31	0.42	1.44	0.47	0.05	2.38	182
Both	216	1.59	0.23	2.13	0.48	0.53	3.37	212

Table 8 : Comparison of means of material inputs used between the machine and bullock used farms for different crops (N=696)

Variable	Aman(HYV)			Boro(HYV)		
	Tiller used farms	Bullock used farms	t-value	Tiller used farms	Bullock used farms	t-value
	Mean	Mean		Mean	Mean	
Seedlings (cost/ha)	881.47	669.43	6.61^{hs}	999.03	859.27	2.22^{s}
Fertilizer (cost/ha)	2581.73	1936.56	5.81^{hs}	3041.86	2842.42	1.55
Insecticides (cost /ha)	760.39	652.40	2.85^{hs}	701.92	587.76	4.04^{hs}
Variable	Aus(HYV)			Wheat		
	Tiller used farms	Bullock used farms	t-value	Tiller used farms	Bullock used farms	t-value
	Mean	Mean		Mean	Mean	
Seedlings (cost/ha)	721.13	668.62	0.87	1833.39	1814.67	0.31
Fertilizer (cost/ha)	2614.97	1739.33	5.73^{hs}	1868.55	2506.78	-4.19^{hs}
Insecticides (cost /ha)	657.82	541.65	2.16^{s}	392.40	325.79	1.21
Variable	Potato			Jute		
	Tiller used farms	Bullock used farms	t-value	Tiller used farms	Bullock used farms	t-value
	Mean	Mean		Mean	Mean	
Seedlings (cost/ha)	11324.82	9073.14	2.42^{s}	845.64	646.42	3.35^{hs}
Fertilizer (cost/ha)	7615.95	5317.71	3.19^{hs}	1534.91	1475.39	0.44
Insecticides (cost /ha)	1141.96	946.83	1.62	380.00	543.46	-0.75

Note : Positive t value means tiller operated farms used more of the services than the bullock operated farms.
Tiller used farms are those which either use machine power or use both sources of power. Bullock used farms are fully dependent on animal power.

Farm level societal gain/loss due to labour displacement and yield gains

The crux of the issue of machine power use (either fully or partially) in land preparation is whether the society as a whole is gaining or losing as such by the introduction of machine tillage of lands in the country. This has been also attempted by estimating the labour income lost by crops due to displacement of human labour (at prevailing market wage) and valuing income generated through increased yields by crops and difference between these two gives net societal loss/gain by per hectare of land (Table 9 and 10)[3]. Per hectare net gain for using machine power (through yield increase) during the year 1999/2000 has been Tk. 2121.00 and loss of labour income was Tk. 971.00 annually. Crops having statistically significant differences in labour displacement and yield gain were taken into consideration (considering all the sample farms).

Estimation of positive net gain per hectare of Tk. 1151.00 supports the view of encouraging uses of machine power in land preparation as much as possible through policy

[3] a. All interaction effects of land preparation and other intercultural farm operations and inputs use are assumed reflected through yield grains. However, only yield gains may not truly reflect profitability.

b. While labour displacement is estimated as income loss meaning implicitly assuming that when they are replaced by machine use remained unemployed elsewhere in the farming or non-farming sector. This should be very stringent assumption while labour shortage is exhibited during peak seasons and in the face of rapidly expanding non-farm sectoral activities.

measures. In the ultimate analysis, society is not losing by the spread of machine power in land preparations rather the benefits outweigh the loss due to even highly pronounced labour displacement effects.

Gain or Loss if Machine Power Completely Replace Animal Power

A comparison has made between the farms only using machine power and the farms only using animal power.

The cost of labour displacement in total has been estimated at Tk. 1582.00 per cropped hectare. Per cropped hectare yield gain (for wheat and jute increase in labour income through increased uses of human labour) has been Tk. 3712.00. Per cropped hectare net gain owing to adoption of machine power has been Tk. 2130.00 (net of loss due to labour displacement) (estimations provided in Tables 12 and 13A & 13B). That is, complete replacement even within the present farm structure and market situation would be economically beneficial if only labour displacement and yield gains are compared.

Table 9 : Comparison of means of yield between pure machine and bullock used farms for different crops

Variable	Aman(HYV)			Boro(HYV)		
	Tiller used farms N=182	Bullock used farms N=102	t-value	Tiller used farms N=255	Bullock used farms N=119	t-value
	Mean	Mean		Mean	Mean	
Yield (tonne/ha)	3.12	3.10	0.17	4.88	4.92	-0.38
Variable	Aus(HYV)			Wheat		
	Tiller used farms N=75	Bullock used farms N=89	t-value	Tiller used farms N=71	Bullock used farms N=42	t-value
	Mean	Mean		Mean	Mean	
Yield (tonne/ha)	2.52	2.86	-2.23^{hs}	2.08	1.89	1.13
Variable	Potato			Jute		
	Tiller used farms N=105	Bullock used farms N=23	t-value	Tiller used farms N=48	Bullock used farms N=31	t-value
	Mean	Mean		Mean	Mean	
Yield (tonne/ha)	12.61	10.18	2.22^{hs}	1.95	1.75	0.74

Note : Positive t value means tiller operated farms used more of the services than the bullock operated farms

This is an estimation reflecting gain and loss of using machine power for land preparation taking into account prevailing market wage rate and value productivity per hectare. Market prices reflect true social values if there is no price interventions/control by the government. For accurate net social cost calculations imported values of tools and machineries have also to be deducted (cost as the span of period of uses)

Total loss = Tk. 633,541.10 (Table 10 sum of column 5th)

Total gain = Tk. 1,005,275.71 (Table 11 sum of column 7th)

N = 696

Table 10 : Labour income lost (farm level societal) due to mechanisation (all farms, N=696)*

Crops	Labour (man-days) reduced (ha) (a)	Total land Area (ha) (b)	Average wage (Tk.) (c)	Total wage income loss (a.b.c)	N	Per farm average income lost due to mechanisation (Tk.)	Per ha income lost (Tk.)
Aman (HYV)	16	189.21	62.14	188,120.15	307	612.76	994.24
Boro (HYV)	7	330.22	61.57	142,321.52	425	334.87	430.99
Aus (HYV)	24	82.18	65.88	129,936.44	143	908.64	1581.12
Potato	61	51.13	55.52	173,162.99	162	1068.90	3386.72
Total wage income loss				633541.10	Per hectare income lost		1598.27

Note. * For wheat and jute, labour displacement owning to farm mechanisation has not been statistically significant and therefore dropped in estimating loss of societal income (see Table 5).

Total land (cultivated by machine power) = 652.74(ha); Per cropped hectare loss 970.59 Per cropped hectare gain 2121.33

Net gain per hectare (2121-970.59) = Tk. 1150.74

Table 11 : Income gained (farm level societal) due to increase in yield between machine and animal power used farms (all farms, N=696)*

Crops	Yield/hectare		Yield difference (A-B) (tonne)	Land (ha)	Price per tonne (Tk.)	Total income gained/lost (Tk.)	Per ha income gained/lost (Tk.)	Per farm gain/loss (Tk.)
	Machine (A) (tonne)	Animal (B) (tonne)						
Boro (HYV)	4.94	4.74	0.2	330.22	5813.00	383,913.77	1162.6	903.33
Aus (HYV)	2.47	2.76	0.29	82.18	5386.00	(-)128,360.23	(-) 1561.94	(-) 897.62 **
Potato	12.88	9.07	3.81	51.13	3973.00	773,961.46	15137.13	4,777.54
Jute	1.80	2.10	0.3	10.36	7799.00	(-)24,239.29	(-) 2339.7	(-) 403.99**
Total land				473.89	Total income gained	1005275.71		

Note. *Yield difference between machanised and animal power used lands of Aman (HYV), wheat has not be been statistically significant and therefore not included in calculation of societal income gained.

** There is no gain in income by mechanisation for Aus (HYV) and jute. Income lost, due to use of machine power also deducted.

Per hectare gain 2121.33

Per hectare loss 970.59

Net gain per cropped hectare 1150.74

Table 12 : Labour income lost (farm level societal) due to mechanisation and by crops (excluding the farms using both sources of power, N=480)*

Crops	Labour (man-days) reduced (ha) (a)	Total land Area (ha) (b)	Average wage (Tk.) (c)	Total wage income lost (a.b.c)	N	Per farm average income lost due to mechanisation (Tk.)	Per ha income lost (Tk.)
Aman (HYV)	21	123.62	62.14	161316.7	187	862.66	1,304.94
Aus (HYV)	33	57.94	65.88	125963.9	93	1,354.45	2,174.04
Total land area		181.56	Total age income lost	287280.6			

Note : * For Boro and potato labour displacement owning to farm mechanisation has not been tatistically significant and therefore dropped in estimating loss of societal income.

Total loss = Tk. 287281 (Table 13 sum of column 5[th])

Total gain = Tk. 251639 (Table 14A a sum of column 8[th] + Table 14B sum of column 5[th])

Per cropped hectare loss Tk. 1582.29

Per cropped hectare gain Tk. 3712.02

Per cropped hectare gain owning to mechanise tillage (Tk. 3712.02-Tk. 1582.29)
=Tk. 2129.73
= Tk. 2130

Net loss = Tk. 35642 (Total loss – Total gain)
Per farm loss = Tk. 74 per year (Net loss/N)
Per ha loss = Tk. 164 per year (Net loss/total cropped area)

Table 13A : Income gained (farm level societal) due to increase in yield between machine and animal power used farms by crops (excluding the farms using both sources of power, N=480)*

Crops	Yield/hectare		Yield difference	Land (ha)	N	Price per tonne (Tk.)	Total income gained/lost (Tk.)	Per ha income gained/lost (Tk.)	Per farm gain/loss (Tk.)
	Machine (A) (tonne)	Animal (B) (tonne)	(A-B) (tonne)						
Aus HYV	2.52	2.86	0.34	50.77	75	5386	(-)92972.05	(-)1831.24	(-)1239.627**
Potato	12.61	10.19	2.42	31.65	105	3973	304304.00	9614.66	2898.133
Total land in hectare				82.42	-	-	-	-	-

Note : *Yield difference between machanised and animal power used lands of Aman (HYV), Boro (HYV), wheat and jute has not be been statistically significant and therefore not included in calculation of societal income gained.

** There is no gain in income by mechanisation for Aus (HYV). There is rather income loss, due to use of machine power.

Table 13B : Labour income gained (societal) due to increased labour use by mechanisation by farm size and crops (excluding the farms using both sources of power, N=480)

Crops	Labour (man-days) reduced (ha) (a)	Total land Area (ha) (b)	Average wage (Tk.) (c)	Total wage income gained (a.b.c)	N	Per farm average income lost due to mechanisation (Tk.)	Per ha income lost (Tk.)
Wheat*	18	28.71	55.09	28469.41	73	389.99	991.62
Jute*	33	6.40	56.05	11837.76	49	241.59	1,849.65
Total land area		35.11					

* There is no loss in labour income by mechanisation for wheat and jute. Labour income gained, due to use of machine power.

Total income gained = (Yield income gained + Labour income gained) – yield income lost

= Tk. (304304+28469+11838) – 92972

= Tk. 251639

Income gained per hectare Tk.2564 (yield increase)

Income gained labour increase per hectare Tk. 1148 Per hectare income gained 3712.02

Per cropped hectare net business return of the land tilled by different power sources

Labour displacement may not reflect actual cost of the farming sector because, displaced labour may be gainfully employed elsewhere in the farming or non-farming sector. Even yield difference may not be able to reflect true returns of resources employed (if not seen in value and relative cost terms of produced outputs). For this gross returns per hectare have been estimated (valuing products and by products) and net business returns were estimated subtracting total costs of productions (all current costs comprising paid-out and home supplied inputs in production activities).

Per hectare business returns were estimated for the crops under study between two groups of farmers using machine power (partially or wholly) and animal power used farms. In terms of totality of all these crops per hectare, net business return was higher (Tk. 662/ha) for machine power used farms and revealed the fact that machine power used farms add to the society more than the bullock power used farms (Table 14)[4]. Farmers were better off in using machine power either fully or partially than the animal power used farms. The society is not losing in any way by the introduction of power tiller in farming operations. Benefits will be much higher if trading activities, repair and mending services and multiple uses of power tillers (other than tillage and haulage) are taken into considerations[5].

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4 To see the comparisons in land productivity all crops grown in an unit of land throughout the year should be taken into consideration. This will include all run-off effects of use of modern factor inputs including adoption of mechanical technology in any crop production activity and its follow up effects.

5 Rahman (1998) reported (by using gross margin technique) that multiple uses of power tiller (using engines) is highly profitable to the tiller owners than the tillage operation. Power tiller owners used the engine of power tiller for irrigating Boro HYV, use tillers as lorry for carrying both farm and non-farm products and threshing of paddy.

Factor Contributions in Value Productivity-A Production Function Approach

R^2_s have slightly improved in case of Transcendental-logarithmic (Translog) production functions for some of the crops (mostly due to increased number of interactive explanatory variables but not satisfactorily improved over CD production functional form (in terms of the number of significant variables or even F-ratios)[6]. Results of estimated CD and Translog production functions are provided in Tables 15 (A-B);

Tables 15 series A (1-2). Results of two production functions of machine power used farms.

Series B (1-2) Results of two production functions of animal power used farms.

Table 14 : Per hectare business return (Tk.) from tiller and bullock used farm

Crops	Tiller used farm			Bullock used farm			
	Total cost (a)	Gross return (b)	Business return (a-b)	Crops	Total cost (a)	Gross return (b)	Business return (a-b)
Aman HYV, N=187	17015	21500	4485	Aman HYV, N=97	16755	21251	4496
Boro HYV, N=256	23593	29860	6267	Boro HYV, N=122	19703	29790	10087
Aus HYV, N=88	16350	15686	(-)664	Aus HYV, N=94	18049	18202	153
Wheat, N=70	11848	17016	5168	Wheat, N=65	13290	16271	2981
Potato, N=162	42080	52962	10882	Potato, N=38	28955	36733	7778
Jute, N=60	18039	18320	291	Jute, N=90	20343	17304	(-)3039
Total business return			26429	Total business return			22456

Net business return of crop production activities per hectare for tiller used farm Tk. 4404.83 and for bullock used farm Tk. 3742.67

Net return (higher) from tiller operated land over bullock operated land (4404.83-3742.67) = Tk. 662.16 per hectare.

A test of homogeneity/equality of both intercepts and slope coefficients was conducted between machine power and draft animal power used farms by using estimated coefficients of the Cobb-Doughlas production function.

The test of homogeneity of production functions between two groups of farmers with the regression results of CD function are presented in Tables 16 (test of homogeneity of production functions of Translog type also yielded similar results as of CD but not reported in saving space).

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[6] Ahmed (1992) also not observed significant difference across production functions in his study and reported ' translog production function specification expressed more or less the same result as the Cobb-Douglas production function' (p. 63).

Table 15A. 1. Production function (CD) for different crops (Tiller operated farms)
Dependent variable: Value productivity per hectare (all variables in natural logarithm)

Crops	Constant	LnPrehar	Irdum	LnCulcos	LnCfi	R^2	F-ratio	N
Aman(HYV)	8.69 $(9.48)^{hs}$	-0.09 (-0.68)	0.14 $(2.46)^{s}$	0.19 $(2.54)^{s}$	0.009 (0.16)	0.05	3.11^{s}	235
Boro(HYV)	5.81 $(8.30)^{hs}$	0.21 $(2.62)^{s}$	0.42* $(7.18)^{hs}$	0.13 $(2.63)^{s}$	-0.15 $(-2.69)^{s}$	0.15	15.25^{hs}	359
Aus(HYV)	10.86 $(5.59)^{hs}$	-0.245 (-0.86)	0.52 $(3.2)^{hs}$	0.13 (0.65)	-0.19 (-1.34)	0.19	4.24^{hs}	76
Wheat	9.34 $(9.38)^{hs}$	-0.04 (-0.11)	0.32 $(3.58)^{hs}$	-0.02 (-0.26)	0.03 (0.28)	0.17	4.58^{hs}	91
Potato	9.16 $(6.42)^{hs}$	-0.23 (-1.16)	-0.08 (-0.44)	0.06 (1.03)	0.28 $(3.00)^{hs}$	0.26	2.65^{s}	34
Jute	3.33 (1.41)	-0.004 (-0.02)	-	0.87 $(2.45)^{s}$	-0.08 (-0.39)	0.12	2.29	57

Note: * See footnote of the results of linear production function. The variable is in natural logarithm.
* Variables-
- Prehar, preharvest labour man-days employed in farm activities per hectare
- Irdum, irrigation dummy, used 1 for irrigated crop, 0 for otherwise
- Culcos, land preparation cost either using tiller or animal power per hectare
- Cfi, costs for fertilizers/manures and insecticides per hectare
- Pre-fixing Ln, the variable transformed into natural logarithm.

Table 15A. 2. Translog production function for different crops (Tiller operated farms)
Dependent variable: Value productivity per hectare (all variables in natural logarithm)

Crops	Independent variable																	
	Constant	LnPreha	Irdum*	LnCulcos	LnCfi	**SqCfi**	SqCul	SqPreha	SqIri	CfiCul	Preha Cul	Preha Cfi	CfiIri	IrCul	Preha Iri	R^2	F-ratio	N
Aman	-17.83	8.58	0.14	-0.41	2.24	**-0.04**	0.29	-0.16	-	0.08	-0.47	-0.56	-	-	-	0.9	2.36^{s}	235
(HYV)	(-0.87)	(2.21)^{s}	(2.47)^{s}	(-0.15)	(1.24)	**(-0.28)**	(1.66)^{c}	(-0.32)		(0.56)	(-1.10)	(-2.16)^{s}						
Boro	-0.91	6.52	-1.19	0.24	-0.05	0.03	-0.23	-1.02	0.09	0.17	0.03	-0.33	0.004	0.002	0.09	0.09	2.43^{hs}	358
(HYV)	(-0.06)	(2.29)^{s}	(-1.26)	(0.14)	(-0.02)	(0.18)	(-2.51)^{s}	(-2.56)^{s}	(1.90)	(1.06)	(0.12)	(-1.23)	(0.05)	(0.03)	(0.91)			
Aus (HYV)	62.73	4.37	0.25	-10.65	-6.16	-0.34	0.73	-4.87	-	0.23	0.82	1.51	-	-	-	0.48	6.00^{hs}	76
	(1.32)	(0.66)	(1.67)^{c}	(-1.54)	(-1.13)	(-0.88)	(0.77)	(-4.76)^{hs}		(0.55)	(0.92)	(2.57)^{s}						
Wheat	48.33	0.20	0.32	-5.07	-5.25	0.04	0.03	-0.008	-	0.64	-0.10	0.07	-	-	-	0.23	2.41^{s}	91
	(2.21)	(0.18)	(3.54)^{hs}	(-1.21)	(-1.52)	(0.09)	(0.09)	(-0.13)		(1.86)^{c}	(-0.91)	(0.60)						
Potato	2.84	4.83	0.19	-0.03	-1.21	0.06	0.03	-0.65	-	0.10	-0.20	0.02	-	-	-	0.37	1.38	34
	(0.12)	(0.99)	(0.67)	(-0.01)	(-0.27)	(0.14)	(0.18)	(-0.71)		(0.54)	(-0.85)	(0.04)						
Jute	-160.84	7.25	-	35.81	4.90	-0.39	-3.15	-0.05	-	-0.63	0.50	-1.45	-	-	-	0.22	1.44	56
	(-1.62)	(1.17)		(1.37)	(0.61)	(-0.46)	(-0.90)	(-0.13)		(-0.80)	(0.79)	(-1.45)						

Note: * per hectare irrigation cost, no dummy variable was used in tiller operated farms because all the farms used irrigation. In animal operated farms, irrigation dummy was used as some of the farms used in irrigation and some produced under rainfed condition.

Table 15B. 1. Production function (CD) for different crops (Animal operated farms)
Dependent variable: Value productivity per hectare (all variables in natural logarithm)

Crops	Constant	LnPrehar	Irdum	LnCulcos	LnCfi	R^2	F-ratio	N
Aman(HYV)	4.73 $(12.72)^{hs}$	0.53 $(7.43)^{hs}$	0.05 (0.79)	0.08 $(2.09)^{s}$	0.25 $(4.86)^{hs}$	0.63	71.41^{hs}	170
Boro(HYV)	7.52 $(9.15)^{hs}$	0.62 $(3.63)^{hs}$	0.41 $(2.19)^{s}$	0.19 $(2.84)^{hs}$	-0.26 $(-4.09)^{hs}$	0.28	13.34^{hs}	140
Aus(HYV)	5.46 $(8.32)^{hs}$	0.73 $(5.90)^{hs}$	0.23 $(2.41)^{s}$	0.16 (2.12)s	-0.07 (-1.05)	0.52	29.49^{hs}	111
Wheat	8.07 $(10.15)^{hs}$	0.02 (0.32)	0.12 $(1.87)^{c}$	0.01 (0.21)	0.17 $(2.33)^{s}$	0.15	3.31^{hs}	80
Potato	9.01 $(7.95)^{hs}$	-0.15 (-1.21)	0.03 (0.18)	0.44 $(4.64)^{hs}$	-0.16 (-1.47)	0.39	7.42^{hs}	50
Jute	7.91 $(6.03)^{hs}$	-0.12 (-0.65)	-	-0.06 (-0.40)	0.39 $(4.01)^{hs}$	0.15	6.00^{hs}	107

Table 15B. 2. Translog production function for different crops (Animal operated farms)
Dependent variable: Value productivity per hectare (all variables in natural logarithm)

Crops	Independent variable												
	Constant	LnPreha	Irdum	LnCulcos	LnCfi	SqCfi	SqCul	SqPreha	CfiCul	PrehaCul	PrehaCfi	R^2	F-ratio	N
Aman	3.91	2.23	0.09	0.57	-0.93	0.38	0.01	-0.20	-0.12	0.06	-0.17	0.68	34.53^{hs}	170
(HYV)	(1.30)	$(2.39)^{s}$	(1.23)	(1.19)	(-1.04)	$(2.63)^{s}$	(0.13)	(-1.03)	(-1.49)	(0.61)	(-1.12)			
Boro	-4.76	3.57	0.50	2.12	-0.75	-.021	0.12	-2.25	-0.34	-0.03	1.00	0.35	6.90^{hs}	140
(HYV)	(-0.31)	(0.95)	$(2.65)^{hs}$	(0.90)	(-0.44)	(-1.13)	(0.53)	$(-2.07)^{s}$	$(-1.68)^{c}$	(-0.08)	$(1.87)^{c}$			
Aus	-11.77	1.73	0.21	2.06	2.28	-0.37	0.11	0.07	-0.09	-0.44	0.23	0.60	15.30^{hs}	111
(HYV)	$(-1.80)^{c}$	(0.98)	$(2.30)^{s}$	$(1.65)^{c}$	(1.48)	$(-2.02)^{s}$	(0.50)	(0.12)	(-0.64)	$(-1.73)^{c}$	(1.04)			
Wheat	26.31	0.03	0.06	-2.97	-1.76	0.12	0.27	-0.12	0.12	0.01	0.05	0.20	1.70	80
	(1.32)	(0.01)	(0.87)	(-0.84)	(-0.82)	(0.85)	(1.63)	(-0.48)	(0.34)	(0.09)	(0.18)			
Potato	-2.35	-2.50	0.11	3.52	0.77	-0.10	-0.15	-0.12	-0.21	-0.005	0.35	0.43	3.06^{hs}	50
	(-0.13)	(-0.76)	(0.42)	(1.58)	(0.28)	(-0.29)	(-0.50)	(-0.33)	(-0.99)	(-0.02)	(0.91)			
Jute	-0.12	-6.82	-	1.20	6.23	-0.49	-0.82	-0.84	-0.32	1.46	-0.02	0.37	6.24^{hs}	106
	(-0.01)	$(-2.03)^{s}$		(0.41)	$(3.27)^{hs}$	$(-2.70)^{hs}$	$(-2.81)^{hs}$	(-1.20)	(-1.47)	$(2.70)^{hs}$	(-0.08)			

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Table 16 : Test of homogeneity of production functions (CD) across farms using different power sources

Crop	Null hypotheses about production function			Computed F-ratio with df for			Inferences drawn		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1 (functions equality)	Test 2 (intercepts equality)	Test 3 (slope equality)
Aman HYV	$H_0 : \beta_{iT} = \beta_{iB}$ i = 0, 1, ...,k	$\alpha_{0T} = \alpha_{0B}$	$\beta_{jT} = \beta_{jB}$ j = 1, ... ,k	$F_c = 9.67$, df. 4, 491	22.73, 1, 493,	3.31, 4, 489	H_0- rejected 1% error level	H_0- rejected 1% error level	H_0- rejected 5% error level
Boro HYV	"	"	"	$F_c = 3.36$, df. 4, 397	-258.12, 1, 405	8.19 4, 405	H_0- rejected 1% error level	H_0- not rejected	H_0- rejected 1% error level
Aus HYV	"	"	"	$F_c = 7.10$, df. 4, 180	0.06, 1, 182	6.87 4, 178	H_0- rejected 1% error level	H_0- not rejected	H_0- rejected 1% error level
Wheat	"	"	"	$F_c = 1.16$ df. 4, 164	-	-	H_0- not rejected	Test not needed	Test not needed
Potato	"	"	"	$F_c = 10.75$ df. 4, 81	3.24 1, 83	9.58 4, 79	H_0 rejected 1% error level	H_0 rejected 5% error level	H_0 rejected 1% error level
Jute	"	"	"	$F_c = 9.91$ df. 3, 157	-61.35 1, 158	2.8 3, 155	H_0- rejected at 1% error level	H_0- not rejected	H_0- rejected 5% error level

Note : Test-1 is for test of homogeneity / equality of both intercept and slope coefficients. If production functions are homogeneous between two groups (if H_0 not rejected) then no separate test of intercept (Test-2) or slope coefficients (Test-3) between production functions is needed.

d.f. degree of freedom.

The important findings emerge from this test is that except wheat crop (where two production functions are homogeneous) the farmers using machine power belong to different technological frontier than the animal power used farms. This amply validate the earlier findings of this study indicating higher productivity per unit area and / or higher return per unit area by the machine power used farms which also use significantly more modern factor inputs in crop production activities.

Overwhelmingly, machine power used crops were Boro HYV and potato and production functions for these two crops were significantly different both in intercept and slope coefficients between the two groups of farm holdings. The initial (base) production conditions (assuming zero use of inputs as specified in the equations), productions were significantly different. That is, Boro HYV and potato crops were initially produced within higher production frontiers by the farms using machine power.

Factors influencing per hectare value productivity

Pre-harvest labour use has not significantly influenced value product (gross revenue per hectare) for the crops under study except Boro HYV for machine power used farms. Labour man-days employed in animal power used farms has significantly influenced receipt of value productivity per hectare for all the rice varieties, (though not for other crops). Marginal value productivity (estimated using elasticity coefficient, geometric mean of value productivity and geometric mean per hectare of labour man-days)[7] shows marginal value productivity (MVP_L) of per labour man-day for Boro HYV equals factor acquisition cost (labour wage per man-day of tiller operated farms). This has been calculated for Aman HYV, Boro HYV and Aus HYV for animal power operated farms which were as follows (only for significant coefficients):

Marginal value productivity of labour and wage rate

Crops	Marginal value productivity (Tk.) of labour		Average pre-harvest wage rate/man-days (Tk.)
	Tiller farms	Animal farms	
Aman HYV	-	98	62
Boro HYV	60	145	60
Aus HYV	-	111	66

Tiller used farms used labour input efficiently ($MVP_L=W_L$) in producing Boro HYV while animal power used farms (where $MVP_L > W_L$) applied relatively too little of labour input. As the labour wage rate (W_L) not surpasses marginal value productivity of labour input for none of the farmers groups, pre-harvest labour uses for the selected crops do not signify use of surplus labour (as the case was not $MVP_L < W_L$) in pre-harvest crop production

[7] Value productivity per hectare times the labour elasticity divided by the mean per hectare labour man-days.

activities. Use of surplus labour has not been there (in using pre-harvest major crop production activities) for crops studied.

Elasticity magnitudes showing negative sign (e.g. expenses of fertilizers of both the groups of farms would result in $MVP_F < F_c$ implying farmers were using too much of this input (in case of fertilizers disproportionate use also may result in negative elasticity magnitudes). That is, farmers of both the groups were failed to use chemical fertilizers/insecticides economically judiciously.

Irrigation has been more productive (more use gives more returns: see the elasticity magnitudes) in machine power used farms than in animal power used farms (significant in case of all crops except potato and jute: for wheat elasticity of pooled regression should be consulted). Irrigation has been more sensitive for the machine power used farms than animal power used farms.

All the input elasticity (significant ones) coefficients except expenses on fertilizers and insecticides are positive and indicate diminishing marginal returns $(0 < \xi < 1)$ on the production function[8]. That is, farmers in general use important inputs on the economic stage of production functions.

Production functions analyses technically proved that the farmers using machine power operate in higher production frontier (technologically advanced) than animal power user farms for all the crops except wheat crop.

IV. CONCLUSIONS AND POLICY IMPLICATIONS

Machine power used farms are more dependent on hired labourers which go in favour of wage labourers and should thus benefit small / marginal farmers in terms of employment. Use of total human labour get reduced for some crops but trend of productivity increase through better soil management and labour income lost (if not at all employed elsewhere) due to decreased use of labour man-days. The apprehensions of increasing labour unemployment with the adoption of mechanised tilling ultimately does not create any negative impact in terms of land productivity or value additions per unit of land and the society rather gains economically with more expansion of mechanised tillage. Multiple use of tiller engines, trading of power tillers, spaire-parts/ fuel-oil and repair services create additional job opportunities in the rural areas. Machine power used farmers should be the pioneers of modern agricultural sector and thus, be protected by policy support for unhindered supply of tillage machines, modern implements /tools and biological factor inputs. Bangladesh Government allowed tax free imports of tractors and power tillers in 1988 (as a way to meet-

[8] $\xi > 1$ or ξ (elasticity) < 0 define areas of production function in which it would not be economically logical for the farmer to operate.

up draft power shortage inflicted by serious flood) and importation from then on increasing every year. Efforts should be taken to introduce locally assembled / made tiller, tractors for allowing rapid expansion of these implements to farmers at relatively cheaper costs. Until the local production of these implements are possible, import should be allowed to many firms as some or a few of them cannot influence market price effectively.

All importation of tillage implement/agricultural implements should be tax free for rapid transformation of agricultural sector. Extension workers should encourage farmers for adoption of machine power for as many crops as possible for attaining increased social gains. This will in turn reduce drudgery of animal stock and increase better health condition for fertility and milk production. Increasing education of the family members would exert acceleration of adoption of modern factor inputs and technological innovations in the farm sector.

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