ADOPTION IMPACT OF TWO WHEEL TRACTOR OPERATED SEEDER IN BANGLADESH

M A Monayem Miah
M Enamul Haque
M Abdul Wohab
John Dixon
Q Mesbahul Alam
M Shirajul Islam
M Israil Hossain
M Elahi Baksh

OCTOBER 2008

Bangladesh Agricultural Research Institute
Joydebpur, Gazipur 1701

International Maize and Wheat Improvement Center
Apdo. Postal 6-641, 06600 Mexico, D.F., Mexico

ACKNOWLEDGEMENT

In the first place, the authors express their deepest indebtedness to the Almighty Allah, for blessing them in the successful completion of this report. The authors obtained help from many individuals during conducting and completing this research work and wish to acknowledge them with gratitude and appreciation.

The authors wish to record their gratitude to Md. Harun-ur-Rashid, Director General, Bangladesh Agricultural Research Institute (BARI), Dr. Md. Azizur Rahman, Director Research, BARI, and Dr. K.C. Roy, Director (T & C), BARI for their encouragement, cooperation, and suggestions in conducting this study.

Authors are also grateful to Mr. Anton Prokash Adhikari, Administrator, CIMMYT Office in Bangladesh for providing necessary support to conduct this study.

The financial help to conduct the study from Impact Targeting and Assessment Unit of CIMMYT is greatly acknowledged.

Authors

ADOPTION IMPACT OF TWO WHEEL TRACTOR OPERATED SEEDER IN BANGLADESH

ABSTRACT

The study was conducted in Rajbari and Dinajpur districts of Bangladesh to assess the impacts of PTOS/HSRT adoption on crop cultivation, service providers' livelihoods, and environment. A total of 410 PTOS/HSRT users and 53 service providers were interviewed for this study. The study revealed that PTOS/HSRT was largely used for land preparation and seed sowing of various crops. The peak period of PTOS/HSRT using was ranged from mid-October to mid-January and the lean period was mid-August to mid-October. Scientists, extension contact, neighboring farmers, and family members played important role in adopting PTOS/HSRT. The use of PTOS/HSRT has created a tremendous impact on farmers' income through crop cultivation. It ensured 16%, 15%, 18% and 18% higher yield for wheat, jute, onion and mungbean, respectively compared to conventional system (PT). This also increased farmers' net income 30%, 23%, 46%, and 45% aforesaid crops, respectively. It saved land preparation costs ranged from 16.98 to 30.67% and seed cost 15.06 to 25.37%. Farmers those used PTOS/HSRT technology received 17.9% higher gross return per hectare than PT using farmers. Due to its multipurpose use, 88% adopters wanted to increase the use of PTOS/HSRT in future. Providing PTOS/HSRT service at farm level was found to be highly profitable as its owner earned average net income of Tk. 81,003 per year. The service providers gained a considerable increase in their land holdings (9.7%), annual income (31.34%), livestock resources (24%), farm equipments (70.53%), household assets (21% to 78%), and dwelling houses (58.75%). The increased income was mostly spent on farm machinery purchase, nutritious food, new cloths, health care, education expenses and making of new houses. It was also found that PTOS/HSRT is environment friendly since it could save 40% of fuel per hectare and emission of 43% less CO_2 into the atmosphere. Service providers stated few problems regarding PTOS/HSRT service which were lack of ridding facility, roller jam, and shallow tilling.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAP, PHOTOGRAPHS AND FIGURES

LIST OF APPENDIX TABLES

CONVERSION FACTORS

1 US dollar	=	Bangladeshi Taka 70.00
1 ha	=	10,000 sqm
1 decimal	=	40.49 sqm

ABBREVIATIONS AND ACRONYMS

Aman rice	=	Monsoon season rice
AO	=	Agriculture Officer
BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Benefit Cost Ratio
BJRI	=	Bangladesh Jute Research Institute
Boro rice	=	Spring season rice (January to mid-April)
Chowki	=	A-four legged wooden bedstead
CIMMYT	=	International Maize and Wheat Improvement Centre
CO_2	=	Carbon Dioxide
DAE	=	Department of Agricultural Extension
FC	=	Fixed Cost
FGD	=	Focus Group Discussion
FMPE	=	Farm Machinery and Post-harvest Process Engineering
ha	=	Hectare
HQ	=	Headquarter
HSRT	=	High Speed Rotary Tiller
HTW	=	Hand Tube Well
IPM	=	Integrated Pest Management
Katcha	=	House with straw roof and thrashed bamboo/jute stick/straw wall
Katcha-pacca	=	House with corrugated iron (CI) sheet roof and thrashed bamboo/jute stick/straw wall
kg	=	Kilogram
MP	=	Muriate of Potash
NARS	=	National Agricultural Research Systems
NGO	=	Non-government Organization
OLS	=	Ordinary Least Square
Pacca	=	House with concrete roof and brick wall
PT	=	Power Tiller (two-wheel tractor)
PTOS	=	Power Tiller Operated Seeder
Rabi	=	Winter cropping season
RCT	=	Resource Conserving Technology
SAAO	=	Sub-Assistant Agricultural Officer
Semi-pacca	=	House with CI sheet roof and brick wall
Sidr	=	Devastating cyclone occurred on November 15, 2007 in Bangladesh
SPSS	=	Statistical Package for Social Science
STW	=	Shallow Tube Well
t	=	Tonnage (1 t = 1000 kg)
Tk.	=	Taka (Bangladeshi currency)
Tool	=	A wooden seat without a back for one person
TSP	=	Triple Super Phosphate
VC	=	Variable Cost
WRC	=	Wheat Research Centre

ADOPTION IMPACT OF TWO WHEEL TRACTOR OPERATED SEEDER IN BANGLADESH

1. INTRODUCTION

1.1 Justification of the study:

During 80's, many studies showed that the use of farm machinery affected significantly to the employment and income of small and marginal farmers and contribute a little to the overall productivity of farming systems in Bangladesh (Jabbar *et al.*,1983; Gill, 1984; Duft, 1986). Since then, this perception has been changed due to many reasons including cropping intensification, hiking crop production cost and increases demand of agricultural products. Also, different agro-based and allied industries have emerged to support farm mechanization (Mannan, 2001). The surplus labour force due to farm machinery use is diverted to other forms of employment in non-farm activities or leisure activities (Campbell 1990). The use of two wheel tractor (so called power tiller) for land preparation and rural transportation has increased rapidly in the country due to its versatile use (Rahman, 1998), lower cost for tillage, lesser time required for cultivation and higher crop yield (Islam 2000; Miah 2000; Miah *et al*., 2002). It provided employment for labourers despite the fact that it reduced human labour requirement for land preparation per unit area (Barton, 2000). The subsequent increase in the economic and social welfare of farmers' households is evident from the overall expansion of two wheel tractor technology all over the country.

Haque *et al*., 2008 reported that about 80% of tillage and land operations and a large proportion of other farm operations are mechanized in Bangladesh. The main power sources are 350,000 Chinese 12 to 16 hp two-wheel tractors and an additional two million Chinese 4 to 16 hp diesel engines which are used to power varied activities including rural road and water transportation for agricultural commodities. This In Bangladesh, small agricultural machinery is being widely used for irrigation pumps, threshers, shellers, winnowers, and mobile rice de-husking/flour mill etc.

Since the mid-90s, research and development work on conservation agriculture (CA)-based resource conservation technologies (RCTs) has started with locally developed small machinery, like minimum tillage or no tillage planters, crop production on permanent bed systems, and residue retention. Moreover, many spare parts for Chinese two wheel tractors and diesel engines are now produced locally. Repair and maintenance mechanics, spare parts retailers, and workshops are available at the village level.

This sort of small-scale mechanization may affect the overall farming and farming activities, employment, and household income of the farmers and service providers which are subject to analytical investigation.

The traditional tillage methods have various shortcomings, such as reduce soil organic carbon at double rate and decrease soil fertility (Grace, 2003), serious water loss and soil erosion (Sayre and Hobbs, 2003), and adverse effect on ecological environment (Grace, 2003). Besides, labour scarcity in planting and harvesting period, and turn-around-time between two crop productions adding fuel to this issue.

Therefore, the concept of conservation tillage or minimum tillage has been arisen all over the world which is new in this country. It has significant environmental benefits, while

providing energy savings (Hatfield and Karlen, 1992). To combat this situation, conservation tillage will be the alternative ways to ensure timely planting, meet up labour shortage, keep crop production at economic level, and enhance cropping intensity.

BARI and CIMMYT has been conducting research and development on resource conserving technologies in Bangladesh since 1995 in collaboration with other NARS partners, NGOs, private sector and farmers in many parts of the country (Map 1) funding from various donors, particularly from USAID.

PTOS is a two wheel tractor (so-called, power tiller -PT in Bangladesh) attachments seed drill which is using for tilling, sowing and laddering operations simultaneously in a single pass. PTOS are widely using for various crop establishments. Most of the grain seed like wheat, paddy, maize, jue, pulses, oilseeds etc can be sown in line. It's width of operation is 1200 mm having six rows sowing capacity at a time. More than 430 PTOS are now in operations and spread over the country (Map 1). The owners of PTOS are using this device for their own land cultivation and earning cash income through custom hiring to other farmers.

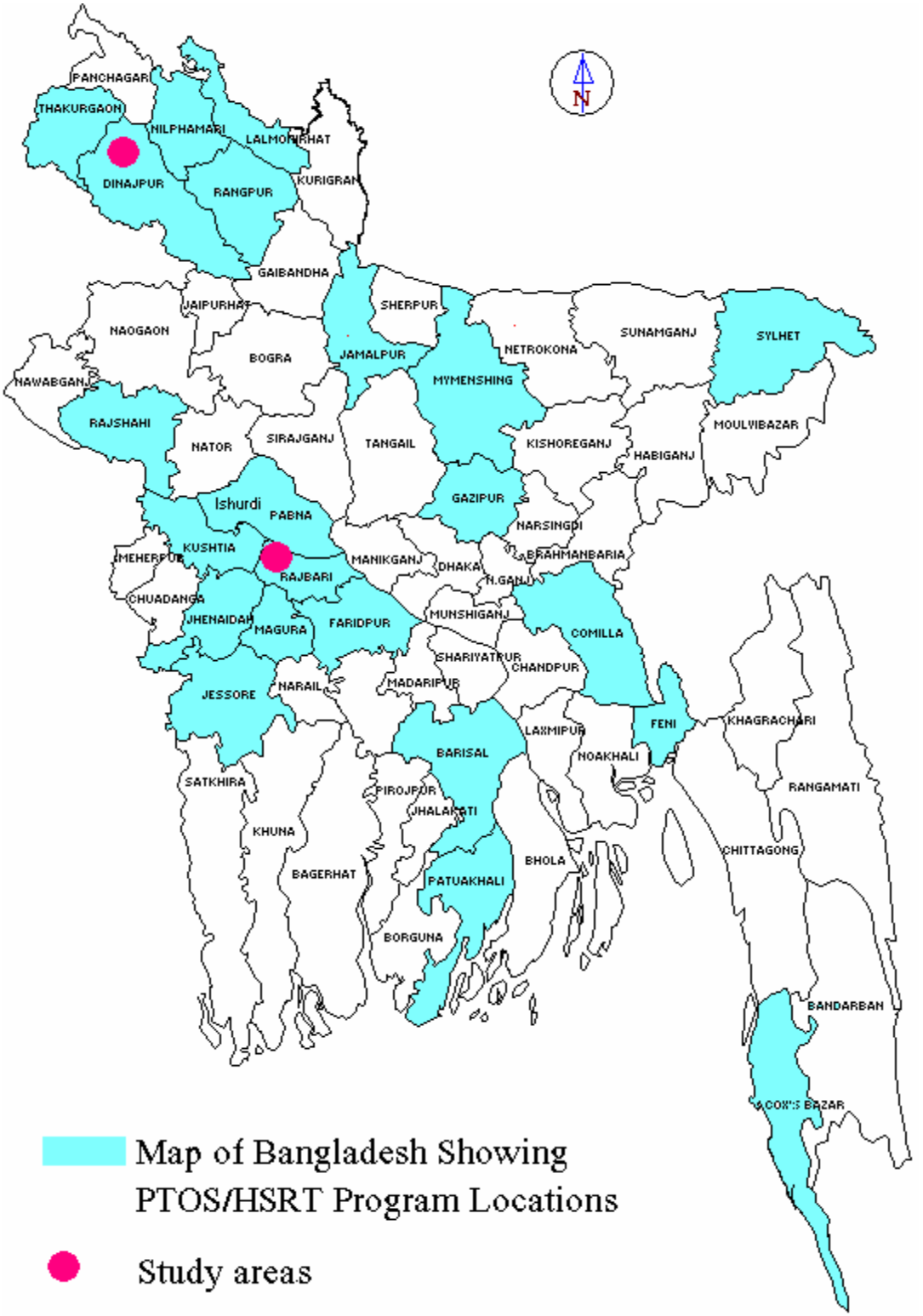
In Dinajpur district, farmers have been using PTOS mainly for sowing wheat, rice and mungbean immediately after harvesting previous crops, but it has not been adopted very well compared to the actual potential of PTOS. On the other hand, it has become popular in Rajbari district mainly for land preparation for onion, garlic, and jute cultivation. In Rajbari case, the service providers have removed seeding unit from PTOS and converted only for High Speed Rotary Tiller (HSRT) Both the farmers and service providers of PTOS are extremely benefiting with this device that needs to be documented and important to find out constraints to its higher adoption. In this background, the present study was undertaken with the following objectives:

1.2 Objectives of the study:

1. To measure the extent of adoption and the use of PTOS in selected areas of Bangladesh.
2. To find out the cost-effectiveness and economic benefit of crop production through PTOS/HSRT in the study areas.
3. To determine the impact of PTOS/HSRT on the livelihoods of service providers.
4. To assess the environmental impacts of PTOS/HSRT.
5. To explore constraints to higher adoption of PTOS and suggest some policy options for higher adoption of PTOS in the country.

2. THE STUDY AREA

The study has conducted in two districts of Bangladesh (Map 1), namely Rajbari and Dinajpur. Details of these districts are described in the following sections.



Map 1: Map of Bangladesh showing districts of PTOS/HSRT program and study districts

2.1 Rajbari district:

2.1.1 Location and area:

Rajbari district is situated between 23□33□ and 23□55□ North latitudes and between $89^0$19' and $89^0$5' East longitudes. It is bordered on the North by Pabna district, on the East by Manikganj district, on the South by Faridpur and Magura districts and on the West by Magura, Jhenaidah and Kustia districts. It holds an area of 1119 sq km (431 sq miles) including river area. It is about 0.76% total area of the country. In respect of size the district ranks 15th among the districts of Dhaka Division and 56 among the 64 districts of the country.

Among four upazilla, Pangsha is the largest having an area of 414.24 sq km (160 sq miles) which is 37% of total area of the district. Goalanda is the smallest constituting an area of 149.03 sq km (57 sq miles) which is 13% of total area of the district. All the upazillas are characterized with more or less similar characteristics.

2.1.2 Soil type and cropping pattern:

The soil of the district is mainly formed by the very young Ganges meander flood plain and the mixed young and the older Ganges meander flood plain. The northern and eastern parts of the district are covered by grey silty clay of the active and very young Ganges meander flood-plan. The central and southern parts of the district are mainly formed of brown silty-clay of the mixed young and the older Ganges flood-plain. The major cropping pattern of the study area in Rajbari district are Jute - Aman rice - Onion, Jute - Fallow - Onion, Jute - Fallow - Wheat, etc.

2.1.3 Climate:

The district bears a mild climate. The maximum and minimum average monthly temperatures are 35.4□c and 12.9^0c respectively as recorded during April, 04-march, 05 by Meteorological Department at selected center Faridpur nearest to the district was 2210 millimeters.

2.1.4 River system:

The Padma, the Jamuna, the Garai and the Kumar are the main rivers flow over the district. The Padma and the Jamuna are navigable throughout the year. These rivers are non-tidal. In the District, Goalanda is a famous steamer station, functioning as a connecting link between Dhaka to Faridpur and other districts of southern part of the country. The total length of the rivers in the district is about 107.64 kms. (41.54 sq miles)

2.1.5 Households and population:

According to the Population Census 2001, the total number of households of Rajbari district was 191 thousand. According to Agriculture Sample Survey-2005 the estimated population of the district was at about 1007 thousand and number of households of the district was 208 thousand. Density of population was estimated as 900 per sq km as compared to 933 per sq km for the country. The percentages of male and female population were 52% and 48% of the total population of the district.

2.2. Dinajpur district:

2.2.1 Location and area:

Dinajpur district is one of the oldest districts of the country. The district lies between $25^0$13' and $25^0$54' north latitudes and between $88^0$23' and $89^0$18' east longitudes. The district is bordered on the north by Panchgar and Thakurgaon districts, on the south by Joypurhat district and India, on the east by Rangpur and Nilphamari district and on the west by Thakurgaon district and India. The total area of the district is 3437.98 sq km of which 19.45 sq km is river and 78.87 sq km is under forest. In respect of size, the district ranks 1st among the 16 districts of Rajshahi division and 11th among the 64 districts of the country.

Among thirteen upazilas, Birganj upzila is the largest having an area of 413.00 sq km which is about 12.01% of the total area of the district. Hakimpur upazila is the smallest with an area of 99.92 sq km which is about 2.90% of the total area of the district.

2.2.2 Soil type and cropping pattern:

The old Himalayan Piedmont plain occupies most of the land of Dinajpur district. It comprises an old part of the Tista alluvial fan with a braided river landscape. There are complex patterns of broad sandy or loamy redges intermixed with shallow channels or basins with mainly loamy soils.

The soil is divided in to two groups' i.e, khiar and poli. In south-east region of the district, the soil in Barind tract belonging to the oldalluvium is prevailing in the form of mixed brown and grey silty loam. In central part, along the little Jamuna and the Karatoya rivers valley, the meander floodplains are pale brown silty loam. The major cropping pattern of the study area in Dinajpur district are Aman rice - Boro rice, Aman rice - wheat, Aman rice - Maize, Aman rice - Wheat - Mungbean, etc.

2.2.3 Climate:

The climate of the district is temperate and pleasant. The district is remarkable for its high temperature, humidity and coldness. The maximum and minimum average monthly temperature ranges between 33.4□c and 11^0 C The dry winter season comes in the month of October and goes off after March. Summer starts from April and continues up to June. The rainfall is generally heavy during July and August. The annual rainfall of the district recorded during April 2004-March 2005 was 2407 millimeters. The level of humidity is around 67% in February and around 84% in July.

2.2.4 River system:

The little Jamuna, the Karatoy, the Purnabhaba, the Dahpa, the Tista and the Tanga are the main rivers flow through the district. These rivers are of little importance for communication. They are navigable is some main rivers by smaller country boats in full rainy season only. The river channels are entrenched about 15 to 20 feet below the surrounding landscape. Total linear length of all the rivers in the district is about 497 kms. It occupies an area of 19.45 sq km, which is 057% of total area of the district.

2.2.5 Households and population:

According to the population Census 2001, the total number of households in Dinajpur district was at about 580 thousand. According to Agriculture Sample Survey-2005 estimated population of the district was 2839510 and number of household was 641 thousand. The density of population was 826 per sq km. The percentage of male and female were 51% and 49% respectively.

3. THE POWER TILLER OPERATED SEEDER (PTOS) AND HIGH SPEED ROTARY TILLER (HSRT)

PTOS is a two wheel tractor (so-called, power tiller in Bangladesh) operated seed drill that are widely used for various crop establishment (Figure 1). Three operations could be done in one operation, i.e., prepare lands with fine tilth, sowing seeds at the 2-3 cm depth, and planking simultaneously. This machine performs well at 15 to 36% of soil moisture level. If optimum soil moisture is exists, the machine could reduce turn-around-time upto zero day in between two crops establishment.

Photograph 1: PTOS in operation in fallow land (left) and in the left-over residue plot (right) after Aman rice harvest

In 1995, Wheat Research Center of BARI and CIMMYT imported two units of PTOS from China and used to conduct many on-station experiments at Wheat Research Center, BARI Regional Station and farmers fields to see the adoptability of the PTOS until 2001. Since 2003, BARI and CIMMYT have undertaken program to transfer the technologies at farmers' level with the funding help from USAID. These PTOS were sold many service providers/farmers of Bangladesh. PTOS performs multipurpose functions in many areas of the country. More than 430 PTOS are now in operations and spread over the country (Map 1). The owners of PTOS are using this device for their own crop cultivation and earning cash income through custom hiring to other farmers. In Dinajpur district, farmers have been using PTOS mainly for sowing wheat, rice and mungbean immediately after harvesting previous crops, but it has not been adopted very well compared to the actual potential of PTOS.

On the other hand, it has become popular in Rajbari district mainly for land preparation for onion, garlic, and jute cultivation. In Rajbari case, the service providers have removed seeding unit from PTOS and converted only for High Speed Rotary Tiller (HSRT), (Figure 2) Both the farmers and service providers of PTOS are extremely benefiting with this device that needs to be documented and important to find out constraints to its higher adoption.

Photograph 1: A High Speed Rotary Tiller

4. METHODOLOGY OF THE STUDY

4.1 Sampling design:

Three upazillas namely Bochagonj, Fulbari, and Dinajpur Sadar from Dinajpur district, and Baliakandi from Rajbari district were purposively selected for this study. In Rajbari district, PTOS is being used for land preparation with fine tilth soil for transplanting onion and garlic seedlings; sowing wheat, jute and sesame seed directly; and preparing seed bed for onion. In Dinajpur district, it is widely used for planting the seeds of wheat, maize, chickpea, lentil, mungbean, jute, and sesame. Nevertheless, PTOS is also being used for land preparation and paddling for rice cultivation in both the areas. In order to measure the cost-effectiveness and economic benefit of PTOS/HSRT for crop production, 255 randomly selected PTOS/HSRT farmers and 155 PT farmers those cultivated onion, wheat, jute, and mungbean were selected from the study areas. Detailed sample size is shown in Table 1. Furthermore, a total of 53 service providers[1] of PTOS/HSRT, distributing 47 persons from Rajbari district and 6 persons from Dinajpur district were randomly selected for interview to assess income and the changes of service providers' livelihood.

Table 1: Sample respondents in the study areas

Crop	Rajbari district		Dinajpur district		All districts	
	PTOS	PT	PTOS	PT	PTOS	PT
1. Wheat	60	40	60	30	120	70
2. Jute	60	40	-	-	60	40
3. Onion	60	40	-	-	60	40
4. Mungbean	-	-	15	5	15	5
All crops	180	120	75	35	255	155

4.2 Data collection:

Data for the present study were collected from the users and service providers of PTOS/HSRT. Data and information were gathered through focus group discussion (FGD), household survey, and case studies. Focus group consisted of different sections of people such as Sub-assistant Agricultural Officer, PTOS/HSRT and spare parts sellers, PTOS/HSRT owners, PTOS/HSRT operators, and few conscious local community people. On the other hand, quantitative and qualitative data and information were gathered from the randomly selected users and service providers of PTOS/HSRT through conducting household survey using pre-tested interview schedules during July, 2008. Some suitable case studies of successful service providers were also conducted to supplement the study. The enumerators were given detailed instructions, and the respondents were given fruit sapling in Rajbari district, and cash incentives as Tiffin and conveyance allowance at Dinajpur district for collecting authentic and reliable data and information for the study.

4.3 Estimation of costs and benefits:

The cost effectiveness and benefits of PTOS/HSRT were measured through analyzing the costs and returns of different crop production under *'With PTOS*' and *'Without PTOS'* situations. Hence, the level of input use, costs of production and different profitability indicators such as gross margin, net return, and benefit cost ratio in different crop

[1] Prepared land on contractual basis.

productions under PTOS/HSRT and PT were calculated separately. The cost of crop production per hectare was calculated by summing up all the costs incurred for various inputs like tillage operations, human labour, seed, manures and fertilizer, pesticides, and irrigation. The gross return per hectare was calculated by summing up the values of different crops grown and their byproducts. T-test was also employed to show the level of significant difference between the costs and returns of crop production under two tillage methods. Collected data were analyzed using different computer software like Micro Soft Excel, SPSS and STATA.

On the other hand, the impacts of PTOS/HSRT on the livelihoods of service providers were assessed through analyzing *'Before'* and *'After'* socio-economic standings of the service providers. Data regarding land holdings, livestock resources, yearly household income, farm equipment, household assets, liability status, and food intake were analyzed and compared for measuring the impacts of PTOS/HSRT service on its provider's livelihoods. The values of different household assets were collected based on present value. For example, a house was built five years back with the amount of Tk.50,000 but due to price hiking, the present value of this house is Tk.70,000 which is used for reporting. Besides, if that farmer invested extra money for renovation and/or extension of the house that amount is also added with the present value in this report. T-test was also employed to show the level of significant difference between two periods. Tabular method of analysis with descriptive statistics was adopted to present the findings of the study.

4.4 Functional analysis:

The following Probit model was carried out to measure the extent of influence of different socio-economic factors of adoption of PTOS/HSRT. The dependent variable of this model was 'adoption of PTOS/HSRT'. Since the dependent variable is dichotomous, OLS cannot be used. The model is as follows.

$$A_i = \alpha + \beta_i X_i + ……..U_i$$

Where,
Ai = Farmers adopting PTOS; (If Yes = 1; Otherwise = 0)
β_i = Coefficients to be estimated (I= 1, 2, 3 …..11)
X_i = Socio-economic variables
α = Intercept, and
Ui = Error term

The socio-economic variables were: The socio-economic variables were: X_1 = Age of the respondent (year); X_2 = Education (Year of schooling); X_3 = Household income (Tk/year), X_4 = Farm size (in decimal); X_5 = Influence of family members (Score); X_6 = Influence of neighboring farmers (Score); X_7= Influence of BARI scientists (Score), and X_8 = Extension contact (Score).

A Cobb-Douglas type revenue function was estimated for crop farming to estimate the effect of changing different inputs on gross return. In order to understand the effect of changes in the tillage methods, a tillage dummy was introduced in the function. This function was estimated using a combined data set from both types of tillage methods, i.e. tillage by PTOS and PT. The coefficient of dummy variable will explain how much PTOS

farmers be benefited compared to PT farmers. The estimated production function is shown below.

$$LnY = b_0 + b_1LnX_1 + b_2LnX_2 + b_3LnX_3 + b_4LnX_4 + b_5LnX_5 ++ b_6LnX_6 + b_7LnX_7 + b_8TD$$

Where, Y = Gross return (Tk/ha), X_1 = Cost of land preparation (Tk/ha); X_2 = Cost of human labour (Tk/ha); X_3 = Cost of crop seed (Tk/ha); X_4 = Cost of fertilizers (Tk/ha); X_5 = Cost of cow dung (Tk/ha); X_6 = Cost of irrigation (Tk/ha); X_7 = Cost of pesticides (Tk/ha); and TD = Tillage dummy (0 for PT and 1 for PTOS). b_0, b_1, b_2, b_3, ... b_8 are the respective estimated coefficients.

5. SOCIO-ECONOMIC PROFILE OF THE PTOS/HSRT AND PT USERS

The adoption of new and improved technologies at farm level is mostly dependent on farmers' socio-economic characteristics. Therefore, an attempt was made to identify different socio-economic characteristics that may influence farmers to adopt PTOS (Table 2).

5.1 Age:

Age is an important factor that influences farmers' decision to adopt improved technologies. The average age of the PTOS and PT farmers were 37.11 years and 38.64 years respectively with minimum age of 17 years and the maximum of 80 years. If we consider different age categories, we find that most of the PTOS and PT farmers were in the age group of 31-45 years followed by the age group of 15-30 years (Table 2).

5.2 Education:

The sample farmers were grouped into five categories based on their level of education. More than half of the PTOS and PT farmers had secondary levels of education. The percentages of primary level educated PTOS and PT farmers were 27.5 and 27.7% respectively. Only 3.1% PTOS and 0.6% of PT farmers were found to have completed their higher level of education. More than 7% and 12% of PTOS and PT farmers had basically no education (Table 2).

5.3 Farming experience:

Length of experience in crop farming is also an important factor that influences farmers' level of adoption for new technologies. The average length of farming experience of PTOS and PT farmer were 18 years and 22 years respectively. Interestingly, the length of experience was found to be same for the PTOS farmers of Rajbari and Dinajpur district (Table 2).

5.4 Training received:

On average, 48% of the PTOS farmers and 17% of the PT farmers received training on different aspects of crop production from the DAE, BARI, BJRI, CIMMYT, and several NGOs. The study found that the number of trained farmers in Dinajpur was much higher than that of Rajbari district.

5.5 Cosmo politeness:

This variable was measured based on the frequency of the respondent's visit to five different places (i.e. neighboring village, Upazila HQ, district HQ, capital city and foreign country) outside his own village. The respondents were asked to mention the number of visit made to different places on a monthly and yearly basis. Different values were assigned, based on importance, for different places of visit. The actual score was then calculated by adding all the values. Possible scores ranged from 0 to 15. The study found that the score calculated for PTOS farmers was higher than that of PT farmers (Table 2).

5.6 Extension contact:

A farmer's dynamic personality can easily be apparent from the extent of contact with different extension agents. The respondents were asked to mention the number of contacts they had with different individuals, media and television on a weekly, monthly and yearly basis. Twelve different extension Medias were considered in this study. All these medias were assigned different values according to their importance. The actual score was measured by adding all the values. The scores for extension contact were ranged from 0 to 48. The PTOS farmers of the study areas were found to be more dynamic compared to PT farmers. PTOS farmers communicated with different extension personnel like SAAO, AO, BARI, and CIMMYT scientists more frequently than PT farmers for getting updated crop production information.

Table 2: Socio-economic profile of PTOS and PT using farmers in the study areas

Items	Rajbari district		Dinajpur district		All districts	
	PTOS users	PT	PTOS users	PT	PTOS	PT
Sample Size	*180*	*120*	*75*	*35*	*255*	*155*
1. Farmers' age (%)						
a) 15-30 years (young)	40	35	34	37	38	28
b) 31-45 years (middle age)	37	34	39	37	38	35
c) 46 and above (old)	23	41	26	26	24	37
2. Level of education (%)						
a) Illiterate	6.1	12.5	10.7	11.4	7.5	12.3
b) Primary	27.2	28.3	28.0	25.7	27.5	27.7
c) Secondary	50.6	50.0	53.3	51.4	51.4	50.3
d) Higher Secondary	11.7	8.3	8.0	11.4	10.6	9
e) Degree and above	4.4	0.8	-	-	3.1	0.6
3. Farming experience (years)	18	23	18	20	18	22
4. Trained farmers (%)	46	16	53	23	48	17
5. Cosmopolitanisms (score)	6.39	5.57	6.03	5.00	6.28	5.44
6. Contact with extension agents (score)	15.29	11.45	15.65	12.63	15.4	11.72
7. Involvement with social organization (%)	11	9	32	23	17	12.3
8. Involvement with innovative activities (%)	48	30	41	29	46	30

5.7 Organizational participation:

The respondent farmers in the study areas participated in different organizations. The study found that 17% of PTOS farmers and 12.3% of PT farmers participated in different local social organizations. The percent of participation by Dinajpur farmers was much higher compared to Rajbari farmers (Table 2).

5.8 Innovativeness:

Innovative activities found in the study areas were use of green manure, use of composed and bio fertilizer, adoption of artificial insemination, production of crops on *Aiel*, and use of IPM strategy in crop production. Forty six percent of the PTOS farmers and 30% of the PT farmers were reported to be involved in different innovative activities (Table 2).

5.9 Land holdings:

The average farm size per household for PTOS and PT farmers were estimated at 1.535 ha and 1.709 ha respectively. The highest farm size was found in Dinajpur both for PTOS and PT households. Again, the PTOS and PT farmers of Rajbari district owned cultivated land higher than the land owned by Dinajpur farmers (Table 3).

Table 3: Farm size with category of land owned by sample farmers

(Figures in ha)

Land category	Rajbari district		Dinajpur district		All districts	
	PTOS	PT	PTOS	PT	PTOS	PT
Sample Size	*180*	*120*	*75*	*35*	*255*	*155*
1. Own cultivated land	1.193	1.356	1.154	1.200	1.181	1.321
2. Rented-in land	0.069	0.040	0.385	0.608	0.162	0.168
3. Rented out land	0.123	0.131	0.103	0.029	0.117	0.108
4. Mortgaged in land	0.117	0163	0.251	0.081	0.157	0.144
5. Mortgaged out land	0.144	0.062	0.009	0.004	0.105	0.049
6. Homestead	0.098	0.116	0.078	0.073	0.092	0.106
7. Orchard	0.119	0.041	0.073	0.045	0.106	0.418
8. Pond	0.062	0.086	0.053	0.079	0.059	0.084
Farm size (ha)*	1.391	1.608	1.880	2.053	1.535	1.709

* Calculation of farm size: (1+2+4+6+7+8) – (3+5)

5.10 Household income:

The yearly household incomes of the PTOS and PT farmers were calculated at Tk. 2,18,174 and Tk. 2,05,157 respectively of which majority income came from crop sale (65-78% of the total income). In the case of PTOS farmer, the contribution of business and service to the total household income were found remarkable. Both PTOS and PT farmers earned more than 7% of total household income from farm machinery (Table 4).

Table 4: Yearly household income of the sample respondents in the study areas

(Figure in Tk/year)

Sources of income	Rajbari		Dinajpur		All area	
	PTOS	PT	PTOS	PT	PTOS	PT
Sample Size	*180*	*120*	*75*	*35*	*255*	*155*
1. Crop sale	124,374	146,134	186,598	206,190	142675	159,695
2. Fruits sale	1,164	1,390	5,201	429	2,352	1,173
3. Livestock sale	13,901	11,790	18,043	11,066	15,119	11,627
4. Service	31,648	12,287	6,112	-	24,137	9,512
5. Business	16,836	10,133	22,760	3,686	18,578	8,677
6. Farm machinery	*18,697*	*12,708*	*7,192*	*20,520*	*15,313*	*14,473*

i) PTOS	11417	-	3440	-	9071	-
ii) PT	-	7,608	-	12,857	-	8,794
iii) STW	2,952	4,050	2,773	4,746	2,899	4,207
iv) Thresher	4,328	1,050	979	2,917	3,343	1,472
Total household income	206,620	194,442	245,906	241,891	218,174	205,157

6. SOCIO-ECONOMIC PROFILE OF THE SERVICE PROVIDERS OF PTOS/HSRT

An attempt was made to identify different socio-economic characteristics of PTOS/HSRT Service Providers in the study areas and presented the results in Table 5.

6.1 Age:

Age is an important factor that may be influenced entrepreneurs' decision to operate PTOS/HSRT as a commercial business. The average age of the PTOS/HSRT owners was 40 years with minimum age of 23 years and the maximum of 90 years (Table 5).

6.2 Education:

The sample service providers were grouped into five categories based on their level of education. More than 47% of service providers completed secondary levels of education, followed by 34% of primary level. Only 3.8% service providers were found to complete their higher level of education. Only 2% service providers were not received any formal education (Table 5).

6.3 Experience with PTOS/HSRT service:

Length of experience of PTOS/HSRT service is also important in future decision making process regarding farm machinery business. The average length of experience of PTOS service providers were 4 years ranging from 2 to 6 years. The highest numbers of service providers were experienced by 3 years in PTOS/HSRT. Detail information of service providers experience with PTOS/HSRT is shown in Table 5.

Table 5: Socio-economic profile of PTOS owner/service provider in the study areas

Items	N	Mean
1. Farmers' age (year)	53	40.0
2. Level of education (%)		
a. Illiterate	2	3.8
b. Completed Primary Level	18	34.0
c. Completed Secondary Level	25	47.2
d. Completed Higher Secondary Level	6	11.3
e. Degree and above	2	3.8
3. Experience with PTOS service (%)		
a. 6 years (2002/03 to 2007/08)	2	3.8
b. 5 years (2003/04 to 2007/08)	6	11.3
c. 4 years (2004/05 to 2007/08)	9	17.0
d. 3 years (2005/06 to 2007/08)	23	43.4
e. 2 years (2006/07 to 2007/08)	13	24.5
4. Source of financing for PTOS (%)		
a. Self	24	45.3
b. Credit	2	3.8
c. Both self & credit	27	50.9
5. Type of farm machineries owned (%)		
a. Power tiller	14	26.4
b. Power thresher	21	39.6

c. Shallow tube well	45	86.8
d. Sprayer	10	18.9
e. Hand weeder	7	13.2

6.4 Source of financing:

Three types of financing sources were reported in the study areas. More than half of the respondents bought PTOS/HSRT by both own cash, cash from commercial banks or PTOS/HSRT sellers, and from CIMMYT. A good number of service providers bought PTOS/HSRT by own cash (Table 5).

6.5 Farm machineries ownership:

The sample service providers in the study areas owned a number of farm implement that were mostly used for renting out to others for earning cash income. The name of these farm implement were power tiller, power thresher, Shallow Tube Well (STW), sprayer, and hand weedier. Table 5 revealed that nearly 86% of sample PTOS/HSRT owners owned STW, 39.6% owned power thresher, and 18.9% owned sprayer. Furthermore, 26.4% of PTOS/HSRT owners bought an additional power tiller for their own use as well as service providing business.

6.6 Service providing for land preparation and seed sowing:

In the study area, the service providers rent out PTOS/HSRT services for land preparation to sow seed or transplant seedlings of various. In 2007-08, the PTOS owners provided land preparation and sowing seeds of 12 different types of crops. Among these, the highest coverage for land preparation to transplant onion followed by rice and jute in the study areas. It was reported that the number of service providers and users for land preparation of PTOS/HSRT is increasing day by day and year after year (Table 6). In 2007-08 season, the use of PTOS/HSRT is reduced (Table 6) due to devastating cyclone '*Sidr*' and heavy rainfall during that time which delayed to dry enough to cultivate *Rabi* crop in this season.

Table 6: Crop-wise land preparation trend by PTOS/HSRT in the study areas

Crops under PTOS/HSRT System	Year of land preparation operations									
	2007-08		2006-07		2005-06		2004-05		2003-04	
	N	Area (ha)	N	Area (ha)	N	Area (ha)	N	Area (ha)	N	Area (ha)
1. Wheat	43	6.134	42	4.960	31	3.931	16	4.336	5	8.826
2. Onion	42	17.166	44	16.243	33	11.919	16	9.097	5	6.049
3. Garlic	42	5.915	44	6.397	33	4.672	15	4.834	5	1.385
4. Jute	45	6.700	41	11.077	30	5.470	15	7.684	4	3.968
5. Rice	41	11.445	37	11.551	25	7.717	14	10.725	2	2.915
6. Sesame	21	5.915	26	2.563	19	1.591	8	2.409	3	1.794
7. Potato	10	1.988	8	2.134	7	0.899	4	1.077	3	0.660
8. Maize	2	15.437	2	14.980	2	6.984	2	2.004	2	2.024
9. Lentil	6	0.490	7	0.498	5	0.551	3	1.008	-	-
10. Black gram	1	0.713	2	1.158	2	0.445	2	0.490	-	-
11. Mungbean	3	0.595	5	0.688	3	0.676	-	-	-	-
12. Tomato	1	8.097	1	20.243	-	-	-	-	-	-
All crops		80.595		92.490		44.854		43.664		27.619

7. ADOPTION AND USE OF PTOS/HSRT AT FARM LEVEL

7.1 Adoption and use of PTOS/HSRT:

CIMMYT and BARI has been working to expand the PTOS/HSRT technologies in the study areas since 2002 (Dinajpur district) and 2003 (Rajbari district). In Baliakandi Upazila of Rajbari district, a large number of farmers are adapted PTOS/HSRT technologies to grow jute, wheat, sesame, mustard, lentil, onion, garlic, rice, and many other crops. They are using the PTOS/HSRT machine for year round crop cultivation. PTOS is used, to some extent, for planting wheat, jute, and lentil, while HSRT is largely used for land preparation for onion, garlic, potato, rice and many other crops in Rajbari areas. Table 7 revealed that out of 120 jute and wheat farmers 57% used PTOS for land preparation along with sowing of seed, and 43% farmers used it only for land preparation. It worth mention that many farmers in Rajbari areas opined that PTOS owner showed negative attitude to sow seeds using PTOS as it requires more concentration on seed dropping, fixing seeding unit with PTOS, etc. On the other hand, most farmers have very low confidence on PTOS regarding seed sowing rather than broadcasting. Because, PTOS sows seed at the 2-3 cm depth from the surface level and this is not visible to farmer before germination.

In Dinajpur areas, the demonstration of PTOS/HSRT is very low compared to Rajbari area. The farmers in this area have been using PTOS mainly for sowing seeds of wheat, rice and mungbean immediately after harvesting previous crops. Besides, HSRT is being used for land preparation for cultivating maize, potato, rice, and many other crops. Table 7 further revealed that nearly all the sampled farmers sown seeds using PTOS.

Table 7: Use of PTOS in seed sowing and tillage operation in the study area

	Rajbari district			Dinajpur district			All districts
	Jute	Wheat	All crop	Wheat	Mungbean	All crop	All crops
Seed sowing	36 (60)	33(55)	69 (57)	60 (100)	14 (93)	74 (99)	143 (73)
Land preparation	24 (40)	27 (45)	51 (43)	-	1 (7)	1 (1)	52 (27)
All types	60 (100)	60 (100)	120 (100)	60 (100)	15 (100)	75 (100)	195 (100)

Note: Figures within parentheses are the percents of total

The number of PTOS/HSRT users along with area coverage is increasing day by day in that study areas. The increasing trends of users and coverage were found to be much higher in Rajbari district than Dinajpur district (Table 8).

Table 8: Farmers' PTOS/HSRT uses trend in the study area

Year	Rajbari district				Dinajpur district				All districts			
	Land Preparation		Seed sowing		Land Preparation		Seed sowing		Land Preparation		Seed sowing	
	N	Area (ha)	N	Area (ha)	N	Area (ha)	N	Area (ha)	N	Area (ha)	N	Area (ha)
2003-04	95	0.588	39	0.293	6	0.041	11	0.071	101	0.555	50	0.244
2004-05	174	0.667	74	0.337	12	1.322	19	0.093	186	0.709	96	0.287
2005-06	208	0.663	95	0.330	30	0.747	46	0.121	238	0.674	141	0.262
2006-07	211	0.616	96	0.361	36	1.350	53	0.343	247	0.723	149	0.354

7.2 Usages pattern of PTOS/HSRT:

The service providers in the study areas were found to provide PTOS/HSRT services almost throughout the year. It can be seen from Figure 1 that the period ranged from mid-October to mid-January was reported to be the peak season of PTOS/HSRT service since most of the *Rabi* crops are grown within these period. On the contrary, the periods ranged from mid-August to mid-October and mid-May to mid-June were treated as lean period for PTOS/HSRT service.

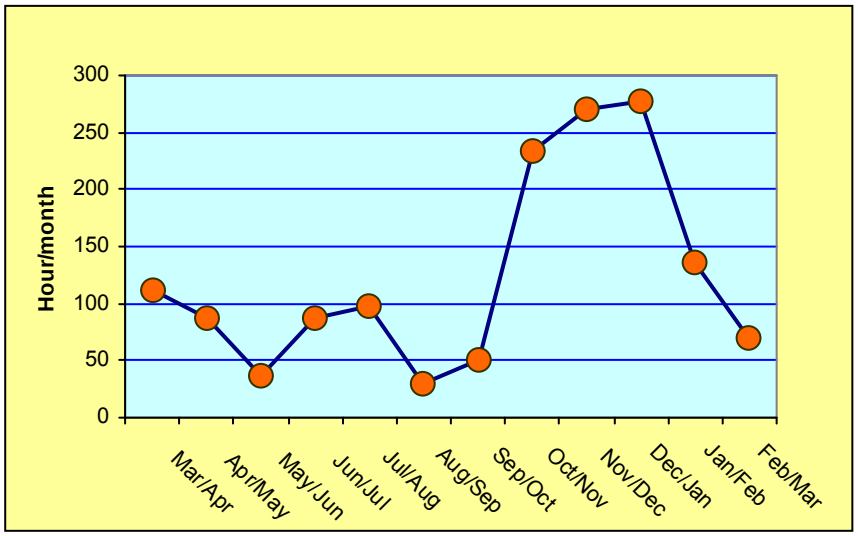


Figure 1: Average use of PTOS/HSRT in the study areas

7.3 Factors affecting PTOS/HSRT Adoption:

The study found that persons from different organizations mainly influenced farmers to use PTOS/HSRT in the study areas. Nevertheless, PTOS/HSRT has strong demonstration effects that easily influenced farmers to use it. The highest percent (91.4% of total) of farmers was influenced by neighbouring farmers to use PTOS/HSRT. The second most important influencing personnel of using PTOS/HSRT were BARI and CIMMYT scientists. In Dinajpur district, family member and extension personnel also played an important role in influencing farmers in cultivating crops using PTOS/HSRT (Table 9).

Table 9: Level of influence of different personnel/organizations for using PTOS/HSRT at farm level

Influencing personnel/organization	Level of influence (%)				Total responses
	Very strong	Strong	Moderate	Less	
Rajbari district (*n = 180*)					
Family members	3.9	3.3	-	-	7.2
Neighbouring farmers	52.8	28.3	13.9	-	95.0
Extension personnel	-	1.7	1.1	2.2	5.0
BARI and CIMMYT scientists	72.2	6.7	-	-	78.9
Dinajpur district (*n =75*)					
Family member	9.3	8.0	16.0	-	33.3
Neighbouring farmer	52.0	20.0	10.7	-	82.7
Extension personnel	2.7	5.3	9.3	-	17.3
BARI scientists/CIMMYT	58.7	8.0	6.7	-	73.3
All districts (*n = 255*)					
Family member	5.5	4.7	4.7	-	14.9
Neighbouring farmer	52.5	25.9	12.9	-	91.4
Extension personnel	0.8	2.7	3.5	1.6	8.6
BARI/CIMMYT Scientists	68.2	7.1	2.0	-	77.3

The adoption of the PTOS/HSRT at farm level is likely to be influenced by various factors. To identifying the most influential factors, the Probit Model was estimated with different variables i.e., age, education, household income, farm size, family influence, scientists influence, and extension contact. Table 10 reveled that all the variables included in the model were not significantly influence PTOS/HSRT adoption. If the influence of family member is increased by 100%, keeping other factors remain constant, the probability of adoption of PTOS/HSRT would increase 95.2%. Similarly, the probability of adoption would be increased by 20.4%, 25.2%, and 5.8% in the case of influence from neighboring farmers, scientists from BARI & CIMMYT, and extension contact, respectively.

Table 10: Estimating probability of increasing adoption of PTOS/HSRT at farm level

Variable	Coefficient	Std error	z-value	P>|z|	Marginal effect	Std error	z-value
Age	-0.00832	0.00561	-1.48	0.138	0.01177	0.00793	1.48
Education	-0.02575	0.02353	-1.09	0.274	0.03641	0.03327	1.09
HH income	-0.00000	0.00000	-1.05	0.294	0.00000	0.00000	1.05
Farm size (ha)	-0.00018	0.00026	-0.68	0.496	0.00025	0.00370	0.68
Family influence	0.65193**	0.27593	2.36	0.018	-0.92197**	0.39023	-2.36
Farmers' influence	0.14401***	0.04930	2.92	0.003	-0.20366***	0.06973	-2.92
Scientist's influence	0.17840***	0.04457	4.00	0.000	-0.25230***	0.06304	-4.00
Extension contact	0.04145***	0.01338	3.10	0.002	-0.05862***	0.01892	-3.10
Constant	-0.15039	0.35043	-0.43	0.668	0.21269	0.49558	0.43

Note: ** and *** means significant at 5% and 1% level. Number of observation= 410, LR Chi^2 (8)=93.05 Prob>chi2 = 0.0000, Pseudo R^2 = 0.1670 Log likelihood = -232.00079

8. COST-EFFECTIVENESS AND BENEFIT OF PTOS/HSRT ON CROP CULTIVATION

The study evaluated the cost-effectiveness and benefit to use of PTOS/HSRT on crop production. The crops under evaluation were wheat, jute, onion, and mungbean. The use of PTOS/HSRT has been created a remarkable impact on input use and crop production at farm level. The empirical results are briefly discussed crop wise below.

8.1 Wheat cultivation:

Wheat is an important cereal crops for both Rajbari and Dinajpur districts. The use of PTOS, significantly reduced the amount of seed uses per hectare in wheat cultivation without affecting grain yield. The study found that PTOS farmers used about 19% less amount of wheat seed compared to PT farmers in the study areas. In case of PTOS farmers, human labour and per unit area fertilizer uses seem slightly higher than that of PT farmers (Table 11) might be due to higher production that need extra labour for harvest and post harvest processing.

Cost analysis revealed that although the total cost of wheat cultivation was slightly higher for PTOS users, but the costs of land preparation, seed, and irrigation were significantly reduced than that of PT users. Threshing cost was significantly higher for PTOS users due to higher crop production (Table 12). The profitability of wheat cultivation also showed an exciting scenario in the study areas. All profitability indicators such as crop productivity, gross margin, net benefit, and rate of return were significantly higher for PTOS users as compares to PT users (Table 13).

Table 11: Input uses pattern in wheat cultivation by PTOS and PT in the study areas

Items	Unit	PTOS/HSRT users (*n = 120*)	PT users (*n = 70*)	Mean difference	P(T<=t) value
Human labour					
Family labour	Man-day/ha	28.55	27.16	1.39	0.5203
Hired labour	Man-day/ha	28.02	28.03	-0.01	0.9960
Seed	kg/ha	126.15	148.41	-22.26***	0.0000
Manure & fertilizers:					
Cow dung	t/ha	4.76	3.34	1.42	0.7664
Urea	kg/ha	163.80	155.25	8.55	0.8120
TSP	kg/ha	97.92	89.66	8.26	0.1985
MP	kg/ha	67.94	70.98	-3.04	0.8966
Gypsum	kg/ha	31.94	27.80	4.14	0.6439
Zinc oxide	kg/ha	1.03	0.96	0.07	0.1495
Boron	kg/ha	0.95	0.75	0.20**	0.0278

Note: '***' and '**' indicate significant at 1% and 5% level respectively.

Table 12: Cost of cultivation of wheat using PTOS and PT in the study areas

Cost heading	PTOS users *(n=120)*		PT users *(n=70)*		Mean difference	P(T<=t) value
	Cost (Tk/ha)	%	Cost (Tk/ha)	%		
A. Variable cost	**29748**	**66.0**	**30140**	**67.6**	**-392**	0.9792
Hired labour	3018	6.7	3001	6.7	17	0.9337
Land preparation	3553	7.9	4280	9.6	-727***	0.0018
Seed	4541	10.1	5346	12.0	-805***	0.0000
Manures & fertilizers:		0.0		0.0		
Cow dung	1535	3.4	1241	2.8	294	0.1955
Urea	1029	2.3	1004	2.3	25	0.7506
TSP	2500	5.6	2396	5.4	104	0.6251
MP	1645	3.7	1733	3.9	-88	0.5993
Gypsum	183	0.4	134	0.3	49	0.1808
Zinc oxide	80	0.2	73	0.2	7	0.8571
Boric acid	95	0.2	70	0.2	25	0.5432
Pesticides	181	0.4	150	0.3	31	0.5786
Irrigation	3423	7.6	3938	8.8	-515*	0.0940
Crop threshing	7551	16.8	6346	14.2	1205***	0.0000
Int. on operating capital	602	1.3	610	1.4	-2	-
B. Fixed cost	**15293**	**34.0**	**14440**	**32.4**	**853**	0.1278
Family labour	3118	6.9	2933	6.6	185	0.4493
Land use cost	12175	27.0	11507	25.8	668	0.1439
C. Total cost (A+B)	**45041**	**100**	**44580**	**100**	**461**	0.2014

Note: (i) Average price of inputs (Tk/kg): Seed-36.06; Cow dung- 0.35; Urea- 6.26; TSP- 25.76; MP- 24.23; Gypsum- 5.41; Zinc oxide- 77.38; Boron- 97.63; and Labour- Tk.108.32/man-day.

(ii) '***' ,'**' and '*' indicate significant at 1%, 5% and 10% level respectively

Table 13: Profitability of wheat cultivation using PTOS and PT in the study area

Cost and return	PTOS users (n=120)	PT users (n=70)	Mean difference	P(T<=t) value
A. Total cost	45,041	44,580	461	0.2014
Variable cost (VC)	29,748	30,140	-392	0.9792
Fixed cost (FC)	15,293	14,440	853	0.1278
B. Total return	104,248	85,868	18380***	0.0000
Wheat grain yield (t/ha)	3.36	2.82	0.54***	0.0000
Return from wheat	101,050	83,422	17628***	0.0000
Return from straw	3,198	2,446	752***	0.0000
C. Gross margin (B-VC)	74,500	55,728	18772***	0.0000
D. Net return (B-A)	59,207	41,288	17919***	0.0000
E. Rate of return (BCR)				
BCR on total cost	2.31	1.93	0.39***	0.0000
BCR on variable cost	3.50	2.85	0.66***	0.0000

Note: Average price of wheat: Tk.30.72/kg; '***' indicates significant at 1% level

8.2 Jute cultivation:

Jute is one of the major cash crops in Rajbari district. Most farmers get lucrative benefit from jute cultivation incurring minimum cash investment. To use PTOS for jute cultivation farmers in the study areas saved about 23% of jute seed per hectare compared to PT using farmers. This saving would be more if all the sampled farmers sow seeds with PTOS. Furthermore, PTOS farmers used the lower amount of cow dung, TSP and MP fertilizers, and slightly higher amount of human labour and urea than that of PT using farmers (Table 14). Table 15 showed that there was no significant difference in the total cost of jute cultivation under PTOS and PT, but significant differences were apparent in the costs of land preparation and seed uses. This means that jute farmers can reduce significant cost for land preparation and seed by using PTOS instead of PT. The productivity of jute under PTOS was found to be significantly higher (15.45%) than the PT users. Nevertheless, the PTOS using farmers in the study areas received significantly higher gross margin and net return than that of PT using farmers (Table 16).

Table 14: Pattern of input use for jute cultivation using PTOS and PT in the study areas

Items	Unit	PTOS farmers (*n = 60*)	PT farmers (*n = 40*)	Mean difference	P(T<=t) value
Human labour					
Family labour	Man-day/ha	77.80	67.14	10.66*	0.0836
Hired labour	Man-day/ha	92.53	98.41	-5.88	0.3488
Seed	kg/ha	5.29	6.87	-1.58***	0.0000
Manure & fertilizers:					
Cow dung	t/ha	1.20	1.88	-0.68	0.3869
Urea	kg/ha	65.91	63.31	2.60	0.7972
TSP	kg/ha	24.63	25.96	-1.33	0.9590
MP	kg/ha	12.00	18.29	-6.29	0.3101

Note: '***' and '*' indicate significant at 1% and 10% level respectively

Table 15: Cost of cultivation of Jute using PTOS and PT in the study areas

Cost heading	PTOS farmer (*n = 60*)		PT farmer (*n = 40*)		Mean difference	P(T<=t) value
	Cost (Tk/ha)	%	Cost (Tk/ha)	%		
A. Variable cost	**20,366**	**46.9**	**21,471**	**50.8**	**-1105**	0.4570
Hired labour	10,084	23.2	10,094	23.9	-10	0.9876
Land preparation	3,943	9.1	4,841	11.4	-898**	0.0239
Seed	447	1.0	599	1.4	-152***	0.0000
Manures & fertilizers:		0.0		0.0		
Cow dung	370	0.9	778	1.8	-408	0.3245
Urea	428	1.0	409	1.0	19	0.7830
TSP	639	1.5	727	1.7	-88	0.7433
MP	262	0.6	372	0.9	-110	0.4782
Irrigation	3,794	8.7	3,230	7.6	564	0.2097
Int. on operating capital	399	0.9	421	1.0		-
B. Fixed cost	**23,018**	**53.1**	**20,824**	**49.2**	**2194****	0.0144
Family labour	8,492	19.6	6,967	16.5	1525**	0.0293
Land use cost	14,526	33.5	13,857	32.8	669	0.1050
C. Total cost (A+B)	**43,384**	**100**	**42,295**	**100**	**1,089**	0.5514

Note: (i) Average price of inputs (Tk/kg): Seed- 85.30; Cow dung- 0.35; Urea- 6.49; TSP- 26.96; MP- 21.86; and Labour- Tk.106.60/man-day.
(ii) '***' and '**' indicate significant at 1% and 5% level respectively

Table 16: Profitability of Jute cultivation using PTOS and PT in the study area

Cost and return	PTOS users (*n = 60*)	PT users (*n = 40*)	Mean difference	P(T<=t) value
A. Total cost	43,384	42295	1089	0.5514
Variable cost (VC)	20,366	21,471	-1105	0.4570
Fixed cost (FC)	23,018	20,824	2194**	0.0144
B. Total return	101,541	87,110	14431***	0.0000
Yield of jute (t/ha)	3.048	2.577	0.471***	0.0000
Return from jute	94,467	79,641	14826***	0.0000
Return from jute stick	7,074	7,469	-395	0.1372
C. Gross margin (B-VC)	81,175	65,639	15536***	0.0000
D. Net return (B-A)	58,157	44,815	13342***	0.0000
E. Rate of return (BCR)				
BCR on total cost	2.341	2.060	0.281***	0.0002
BCR on variable cost	4.986	4.057	0.929***	0.0012

Note: Average price of jute: Tk. 30,980/t
'***' and '**' indicate significant at 1% and 5% level respectively

8.3 Onion cultivation:

Onion is one of the most important cash crops to the farmers of Rajbari district. A plenty of farmers in this area use HSRT for land preparation to transplant onion and garlic seedling. The study revealed that in onion cultivation some differences were found in the application of fertilizers by HSRT and PT using farmers, but except cow dung these differences were not significant at all (Table 17).

Cost analysis revealed that there was no significant difference found in the total cost of onion cultivation under HSRT and PT, but the cost for land preparation using HSRT was significantly reduced compared to PT users. On the other hand, HSRT using farmers transplanted more number of onion seedling per unit area compared to PT using farmers because of better tilth prepared land has given facilities to transplanting more seedlings

in per unit area. The cost for cleaning onion was also significantly higher for HSRT using farmers compared to PT farmers due to higher productivity (Table 18). The yield of onion under HSRT was 18.47% higher with 1% significant level than the yield of onion under PT using farmers. Nevertheless, the HSRT using farmers in the study areas received significantly higher gross margin and net return than that of PT farmers. The rates of returns were also significantly higher for HSRT using farmers (Table 19).

Table 17: Input use pattern for onion cultivation using PTOS and PT in Rajbari district

Items	Unit	PTOS users *(n = 60)*	PT users *(n = 40)*	Mean difference	P(T<=t) value
Human labour					
Family labour	Man-day/ha	139.34	139.32	0.02	0.9964
Hired labour	Man-day/ha	84.78	79.67	5.11	0.3536
Seedling	Tk/ha	13463	11023	2440***	0.0000
Manure & fertilizers:					
Cow dung	ton/ha	1.95	1.60	0.35*	0.0985
Urea	kg/ha	162.58	151.46	11.12	0.7923
TSP	kg/ha	104.38	129.85	-25.47	0.4620
MP	kg/ha	79.84	80.61	-0.77	0.7741
Gypsum	kg/ha	25.37	25.80	-0.43	0.5668
Zinc oxide	kg/ha	1.14	2.21	-1.07	0.6403
Boron	kg/ha	0.37	0.71	-0.34	0.5324

Note: '***' and '*' indicates significant at 1% and 10% level

Table 18: Cost of production of onion using PTOS and PT in Rajbari district

Cost item	PTOS users (*n = 60*)		PT users (*n = 40*)		Mean difference	P(T<=t) value
	Cost (Tk/ha)	%	Cost (Tk/ha)	%		
A. Variable cost	**41,737**	**59.4**	**42048**	**59.8**	**-311**	0.5330
Hired labour	8,913	12.7	8153	11.6	760	0.1831
Land preparation	4,437	6.3	6400	9.1	-1963***	0.0000
Seedling	13,463	19.2	11023	15.7	2440***	0.0000
Manure & fertilizers:						
Cow dung	549	0.8	410	0.6	139	0.4736
Urea	1057	1.5	984	1.4	73	0.4785
TSP	2499	3.6	3464	4.9	-965***	0.0106
MP	1691	2.4	1860	2.6	-169	0.4994
Gypsum	152	0.2	155	0.2	-3	0.9604
Zinc oxide	114	0.2	221	0.3	-107	0.2639
Boric acid	45	0.1	85	0.1	-40	0.5837
Pesticides	600	0.9	787	1.1	-187	0.3660
Irrigation	4746	6.8	5520	7.9	-774	0.2477
Crop cleaning	2653	3.8	2162	3.1	491***	0.0000
Interest on operating capital	818	1.2	824	1.2	-6	-
B. Fixed cost	**28553**	**40.6**	**28223**	**40.2**	**330**	0.6669
Family labour	14673	20.9	14314	20.4	359	0.5563
Land use cost	13880	19.7	13909	19.8	-29	0.9306
C. Total cost (A+B)	**70290**	**100**	**70271**	**100**	**19**	0.7047

Note: (i) Average price of inputs (Tk/kg): Cow dung- 0.29; Urea- 6.50; TSP- 25.03; MP- 21.98; Gypsum- 6.0; Zinc oxide- 100; Boron- 120; and Labour- Tk.104.10/man-day

(ii) '***' and '**' indicate significant at 1% and 5% level respectively.

Table 19: Profitability of onion cultivation using PTOS and PT in Rajbari district

Cost and return	PTOS users *(n = 60)*	PT users *(n = 40)*	Mean difference	P(T<=t) value
A. Total cost	70290	70271	19	0.7047
Variable cost (VC)	41737	42048	-311	0.5330
Fixed cost (FC)	28553	28223	330	0.6669
B. Total return	172985	125401	47584***	0.0000
Yield of onion (t/ha)	10.61	8.65	1.96***	0.0000
Return from onion	172985	125401	47584***	0.0000
C. Gross margin (B-VC)	131248	83353	47895***	0.0000
D. Net return (B-A)	102695	55130	47565***	0.0000
E. Rate of return (BCR)				
BCR on total cost	2.461	1.785	0.676***	0.0000
BCR on variable cost	4.145	2.982	1.162***	0.0000

Note: Average price of onion: Tk. 15.63; '***' indicate significant at 1% level respectively.

8.4 Mungbean cultivation:

Mungbean is a newly adopted potential and remunerative pulse crop in Dinajpur district. Farmers in this area mostly using power tillers for land preparation to cultivate mungbean along with many other crops. Currently, some farmers are using PTOS for mungbean planting in single pass operation. The study revealed that PTOS using farmers used 36.24% higher amount of seed per hectare compared to PT farmers. On the other hand, PT farmers used more fertilizer than that of PTOS farmers (Table 20). Cost analysis revealed that the total cost of production was significantly higher for PTOS farmers compared to PT farmers due to incur higher cost for seed, fertilizers and irrigation. However, land preparation using PTOS required less unit cost (30.41%) than that of PT (Table 21). The farmers who used PTOS received 18.43% higher yield than PT farmers. Nonetheless, the PTOS using farmers in the study areas received significantly higher gross return and gross margin per hectare compared to PT using farmers (Table 22).

Table 20: Pattern of input use in mungbean cultivation in Dinajpur district

Items	Unit	PTOS users *(n = 15)*	PT users *(n = 5)*	Mean difference	P(T<=t) value
Human labour					
Family labour	Man-day/ha	23.69	24.84	-1.15	0.8503
Hired labour	Man-day/ha	40.11	37.00	3.11	0.6113
Seed	kg/ha	20.42	13.02	7.40***	0.0049
Manure & fertilizers:					
Cow dung	ton/ha	2.09	-	2.09	-
Urea	kg/ha	15.06	38.36	-23.30	0.2613
TSP	kg/ha	3.48	-	3.48	-
MP	kg/ha	2.49	-	2.49	-

Table 21: Cost of mungbean cultivation by using PTOS/HSRT and PT in Dinajpur district

Cost Item	PTOS users *(n = 15)*		PT users *(n = 5)*		Mean difference	P(T<=t) value
	Cost (Tk/ha)	%	Cost (Tk/ha)	%		
A. Variable cost	**10603**	**46.6**	**9457**	**44.9**	**1146**	0.1659
Hired labour	4317	19.0	4180	19.8	137	0.8607
Land preparation	2181	9.6	3134	14.9	-953***	0.0020
Seed	1384	6.1	973	4.6	411**	0.0197
Manure and Fertilizers:						
Cow dung	830	3.6	-	-	830**	0.0289
Urea	93	0.4	237	1.1	-144	0.2195
TSP	98	0.4	-	-	98	0.2044
MP	70	0.3	-	-	70	0.3343
Pesticides	639	2.8	748	3.6	-109	0.7989
Irrigation	783	3.4	-	-	783**	0.0121
Interest on operating capital	208	0.9	185	0.9	23	-
B. Fixed cost	**12144**	**53.4**	**11612**	**55.1**	**532**	0.5024
Family labour	2552	11.2	2720	12.9	-168	0.7925
Land use cost	9592	42.2	8892	42.2	700	0.5488
C. Total cost (A+B)	**22747**	**100**	**21069**	**100**	**1678***	0.0758

Note: (i) Average price of inputs (Tk/kg): Seed- 69.75; Cow dung- 0.364; Urea- 6.20; TSP- 28.00; MP- 28.00; and Labour- Tk.109.00/man-day.
(ii) '***' '**' and '*' indicate significant at 1%, 5% and 10% level respectively.

Table 22: Profitability of mungbean cultivation by using PTOS and PT in Dinajpur district

Cost and return	PTOS farmer *(n = 15)*	PT farmer *(n = 5)*	Mean difference	P(T<=t) value
A. Total cost	22747	21069	1678*	0.0758
Variable cost (VC)	10603	9457	1146	0.1659
Fixed cost (FC)	12144	11612	532	0.5024
B. Total return	36977	28853	8124**	0.0123
Yield of mungbean (t/ha)	0.662	0.54	0.122*	0.0560
Return from mungbean	35355	27043	8312**	0.0139
Return from straw	1622	1810	-188	0.6601
C. Gross margin (B-VC)	26374	19396	6978*	0.0556
D. Net return (B-A)	14230	7784	6446**	0.0336
E. Rate of return (BCR)				
BCR on total cost	1.626	1.369	0.256*	0.0564
BCR on variable cost	3.487	3.051	0.436	0.3949

Note: Average price of mungbean: Tk. 52.75
'**' and '*' indicate significant at 5% and 10% level respectively.

8.5 Factors influencing users' income

To estimate the effect of changing different inputs on gross return, a Cobb-Douglas type production function (measured in terms of gross value of output) was estimated for crop farming under tillage operation by PTOS and PT. Estimated values coefficients shown in Table 23 reveal that 61.2% of the variation of the gross return is explained by the eight explanatory variables included in the model. The output elasticity of human labour is 0.305 which is positively significant at 1% level and indicates that, holding the other variables constant, a 1% increase in the cost of human labour, will lead to a 0.305%

increase in the gross return. Similarly, the elasticity of seed, fertilizers, manure, and irrigation are 0.110, 0.024, 0.014 and 0.030 which are positively significant at 1% level. Except pesticide use, all other inputs have positive and significant impacts on increasing gross return. The coefficient of dummy variable reveals that the farmers using PTOS technology would have a 17.9% higher gross return per hectare than PT using farmers. The co-efficient of the tillage dummy is significant at 1% level. The estimated return to scale is 0.679 which indicates increasing return scale since it is less than unity.

Table 23: Estimated values coefficients of Cobb-Douglas revenue function

Variable	Coefficients	Std. Err.	t-value	P>t
Constant	6.994***	0.2654	26.35	0.0000
Cost of land preparation (X_1)	0.034	0.0307	1.09	0.2750
Cost of labour (X_2)	0.305***	0.0208	14.62	0.0000
Cost of seed (X_3)	0.110***	0.0122	8.97	0.0000
Cost of fertilizer (X_4)	0.024***	0.0061	3.81	0.0000
Cost of manure (X_5)	0.014***	0.0033	4.04	0.0000
Cost of irrigation (X_6)	0.030***	0.0059	5.07	0.0000
Cost of pesticides (X_7)	-0.017***	0.0041	-4.08	0.0000
Tillage dummy (TD)	0.179***	0.0245	7.28	0.0000
N	410			
R^2	0.6117			
F (8, 401)	78.98***			

Dependent variable, Y = Gross return (Tk/ha)

9. FARMERS' ATTITUDES TOWARD PTOS/HSRT USE

9.1 Willingness to increase PTOS/HSRT use:

The PTOS adopting farmers were asked to mention the possibility of increasing the use of PTOS for land preparation and sowing seed in the next year. About 88% adopters indicated that they would increase PTOS use in the next year. Among all adopting farmers, Dinajpur farmers showed the highest level of interest in increasing the use of PTOS. The average size of land would be cultivated by PTOS was 0.254 ha (Table 24).

Table 24: Farmers' opinion regarding increase in PTOS use for the next year

Type of reasons	% of responses		
	Rajbari district	Dinajpur district	All districts
1. Willingness to increase			
a) Increase	86	93	88
b) Not increase	15	7	12
c) Amount of area to be increased (ha)	0.184	0.324	0.254
2. Reasons for increasing	*(n = 154)*	*(n = 70)*	*(n = 224)*
a) Less cost for land preparation	94	86	92
b) Excellent tilth of soil	97	87	94
c) Required less seed	93	94	93
d) Higher yields	94	84	91
e) Required less time for land preparation	83	59	75
f) Easy to weeding	58	37	52
g) Required less irrigation	31	6	23
3. Reasons for not increasing	*(n = 26)*	*(n = 5)*	*(n = 31)*
a) PTOS are not available during pick-period	96	100	97
b) Don't have enough land	77	60	74
c) Less depth tillage	58	40	55

The PTOS using farmers also mentioned various reasons regarding the increased used of PTOS for land preparation. They would increase PTOS use in the next year because, it incurred lower cost (92%), tilth soil in a very good way (94%), could save significant amount of seed per hectare (93%), and helped to produce significantly higher yield (91%). Some of the respondents also experienced with less irrigation requirements and easy weeding environment during crop cultivation. Some of the PTOS using farmers mentioned various reasons regarding not increasing the use of PTOS for the next year. The important reason was opined to be the scarcity of PTOS during peak crop establishment period. The second most important reason was the lack of enough land to be prepared for crop cultivation using PTOS. Due to lower depth in tillage about 55% respondent of that category did not want to increase the use of PTOS for the next year (Table 24).

9.2 Constraints to PTOS/HSRT use:

The PTOS using farmers encountered few problems during PTOS use. They mentioned more than one problem regarding this issue. Most farmers believe that the numbers of PTOS available in the study areas are not sufficient compared to local demand. Many farmers of both study areas spent a lot of time to hire PTOS during peak cultivation period. Therefore, about 59% adopters mentioned this as a problem. PTOS has no riding facility during operating for operators, on the other hand they identified it requires more energy to move from one place to another on the other. About 32% operators faced this problem during tillage operation. Sometimes soil particles store in the roller during land preparation that create problems for proper seed placement. A good number farmer (24.3%) stated this as a problem. The other problems regarding PTOS use were identified as - lack of spare parts in the local market, higher fuel cost, and low depth tillage (Table 25).

Table 25: Problems encountered by sample farmers during PTOS/HSRT use

Type of problem	% responses		
	Rajbari district	Dinajpur district	All districts
Sample number	*180*	*75*	*255*
1. Scarcity of PTOS/HSRT in peak season	52.8	73.3	58.8
2. Driving by walking	30.6	34.7	31.8
3. Soil store in roller	25.6	21.3	24.3
4. Spare parts are not always available	16.1	13.3	15.3
5. Fuel cost is high	13.3	12.0	12.9
6. Lower dept in cultivation	11.1	12.0	11.4

10. ECONOMICS OF PTOS/HSRT OPERATIONS AT FARM LEVEL

10.1 Cost and benefit of PTOS/HSRT operations:

The total cost of PTOS/HSRT operations at farm level comprised variable cost (VC) and fixed cost (FC). Variable costs included the costs of fuel and oil, driver's salary, repair, maintenance, spare parts, and miscellaneous expenses. Depreciation of PTOS/HSRT and interest on investment were taken as fixed cost. The total cost of PTOS/HSRT operations was Tk.49,507 ($707). The share of VC and FC were 63.6% and 36.4% respectively. Among cost items, the highest cost was for fuel and oil (28.9%) followed by depreciation of (23.0%) and driver's salary (Table 26).

The service providers of PTOS/HSRT were opined to be highly profitable through renting out their PTOS/HSRT service to other farms in the study areas. The area under land preparation by PTOS/HSRT operations per year ranged from 6.721 ha to 71.255 ha with an average of 28.373 ha. Again, the custom hiring charge of PTOS/HSRT ranged from Tk. 4,491 ($64) to Tk. 5,614 ($80) per hectare. Based on this information, the annual gross income received from PTOS/HSRT service was worked out. The average gross income received by a sample service provider was Tk. 1,30,510 ($1,864) per year. The annual net returns over total cost and VC were calculated at Tk. 99,042 ($1,415) and Tk. 81,003 ($1,157) respectively. The average rate of return on investment was 2.64 implying that PTOS/HSRT operations at farm level were highly profitable (Table 26).

Table 26: Average yearly income for PTOS/HSRT service provider in the study area

Cost and benefit	Minimum (Tk)	Maximum (Tk)	Mean (Tk)
Sample size (N=53)			
A. Variable cost	4,345	97,567	31,468 (63.6)
Fuel and oil	3,245	41,067	14,302 (28.9)
Salary for driver	0	36,000	10,566 (21.3)
Repair and maintenance	400	8,500	2,577 (5.2)
Spare parts	500	6,000	1,757 (3.5)
Miscellaneous	200	6,000	2,266 (4.6)
B. Fixed cost	12,852	20,528	18,039 (36.4)
Depreciation	8,100	12,938	11,369 (23.0)
Interest on investment	4,752	7,590	6,670 (13.5)
C. Total cost (A+B)	17,197	1,18,095	49,507 (100)
D. Gross income	37,727	3,20,000	1,30,510
Total area under tillage (ha)	6.721	71.255	28.373
Rental charge for PTOS/HSRT (Tk/ha)	4,491	5,614	4,724
E. Net income			
Over variable cost (D-A)	33,382	2,22,433	99,042
Over total cost (D-C)	20,530	2,01,905	81,003
F. Rate of return (BCR)			
Over variable cost (D/A)	8.68	3.28	4.15
Over total cost (D/C)	2.19	2.71	2.64

Note: Average price of PTOS/HSRT = Tk. 1,01,057; Price of diesel = Tk. 42/litre; Interest rate = Tk.12/year; Life of PTOS = 8 years; Salvage value PTOS = 10% of purchase price.
Figures within parentheses are percentages of total cost

10.2 Break-even analysis:

An attempt has been made to calculate break-even point of PTOS operation for the service providers based on fixed cost and variable cost of PTOS which are calculated from farm level data on machine price, depreciation cost, interest on investment, machine life, and income from PTOS, etc. The estimated annual fixed cost, variable cost, and income were Tk. 18,039.00 ($258), Tk. 1,109.08 ($15.8), and Tk. 4,717.00 per hectare respectively. The Figure 2 shows that the break-even use of PTOS is 5 ha of land per year. Break-even point is such a point where a service provider can operate PTOS on no loss no profit basis. Therefore, the service providers in the study area have to cultivate more than 5 ha of land per year for make it profitable.

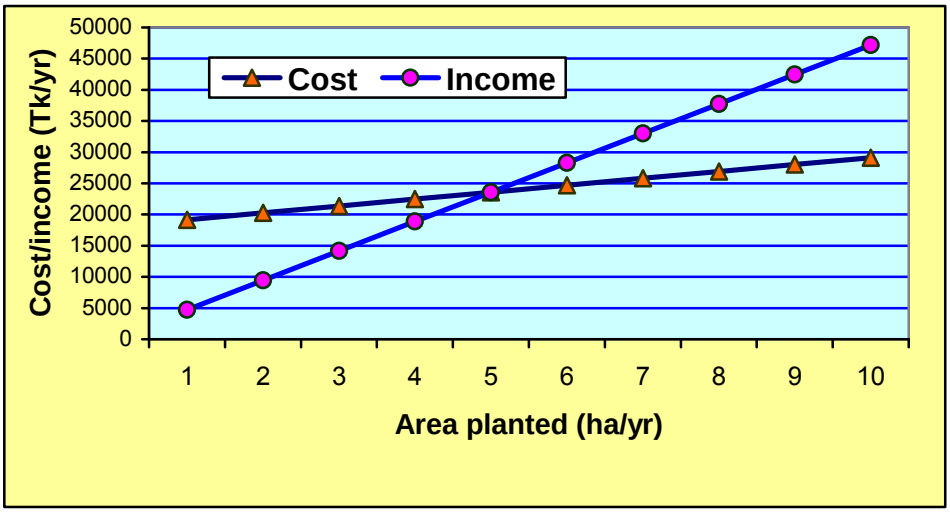


Figure 2: Break-even analysis for a PTOS operation

10.3 Environmental benefits of PTOS/HSRT operations:

The use of PTOS/HSRT is environment friendly since it performs seeding and tilling operations with minimum disturbance of soil and pollute environment less that of conventional tilling method done by power tiller. It was opined that one or two pass was enough for tilling soil surface for crop establishment by PTOS/HSRT, whereas conventional tillage needed 4 or 5 pass with deep tillage. Table 27 showed that reduced tillage system saved 40% of diesel fuel per hectare per year and 43% less emission of CO_2 into the atmosphere. It was found from another study (Hossain et al., 2008) that reduced tillage method saved 94 liter fuels per hectare per year and emission 44% less CO_2 into the atmosphere.

Table 27: Comparative scenario of diesel fuel use in conventional and reduced tillage methods in the study areas

Particulars	Conventional tillage	Reduced tillage by PTOS/HSRT	Amount saved	
			Amount	%
No. of pass used	4-5	1-2	3	200
Total diesel used (Liter/year)	25264	18045	7219	40.0
Total CO_2 emission (ton/year)	65.69	45.92	19.77	43.0
Diesel used (Liter/ha/year)	16.80	12.00	4.80	40.0
CO_2 emission (Liter/ha/year)	43.68	30.54	13.14	43.0

Note: Total area under tillage operation = 1503.789 ha
CO_2 emission from 1.0 liter of diesel = 2.6 kg (Grace, 2003)

10.4 Problems of PTOS/HSRT services:

The service providers in the study areas mentioned that they did not found any major problem except few minor things. About 38% of total service providers did not face any problem during renting out of PTOS/HSRT service to the farmers. Among different problems, higher diesel fuel price was ranked first which was mentioned by over 60% of the service providers. Driving of PTOS/HSRT by walking sometimes create problem for the service providers. The non-availability and higher price of spare parts and roller jam due to soil store were mentioned by 47.2% and 28.3% of the service providers as problems. Some service providers told that trained and efficient driver become scares especially in the peak season (*Rabi* season). A few respondents also mentioned that PTOS/HSRT ploughed land with lower dept and for this reason many farmers complained to them (Table 28) as they preferred deep tillage which is not required to grow the said crops.

Table 28: Problems encountered by sample service provider of PTOS/HSRT

Type of problem	Responses *(N = 53)*	
	Number	%
1. No problem at all	20	37.7
2. Fuel cost is high	32	60.4
3. Driving by walking	28	52.8
4. Non-availability and higher price of spare parts	25	47.2
5. Soil store in roller/roller jam	15	28.3
6. Scarcity of trained driver	12	22.6
7. Lower dept in cultivation	10	18.9
8. Others*	8	15.1

***** Difficult to drive during rainy season; unable to drive at night; licking fuel from reservoir; problem in radiator and sprocket ,

10.5 Precautions taken during PTOS/HSRT operations:

CIMMYT and BARI has conducted training to develop skill and safe-guard of the operators. The sample service providers were asked to mention the type of precautions that were adopted from the training before and during PTOS/HSRT operations. They mentioned more than one answers regarding this issue. About 76% of total service providers told that they checked out the level of fuel, oil, water in the radiator, and air-pressure in the wheels before its operations. Nearly 68% respondents put on tight fitting dress before driving the PTOS/HSRT as it is highly recommended in the training. Spreading seed on crop field in a proper way is a prerequisite for attaining higher yield and reducing cultivation cost. That's why 47.2% service providers checked the dropping of seed frequently in the time of seed sowing. One forth of the respondents was reported to drive PTOS/HSRT slowly in low lying areas and turning point of the road (Table 29).

Table 29: Precautions taken by the service providers during PTOS/HSRT operations

Type of precaution	Responses *(N = 53)*	
	Number	%
1. Check fuel, oil , water in the radiator, and air pressure in wheels	40	75.5
2. Wear tight fitting dress	36	67.9
3. Check dropping of seed frequently	25	47.2
4. Check nut-bolt	15	28.3
5. Drive slowly in low lying area	13	24.5

11. SOCIO-ECONOMIC IMPACTS OF PTOS/HSRT ON LIVELIHOODS OF THE SERVICE PROVIDERS

The present study has found that PTOS/HSRT has positive and direct effects on its owners in generating employment and income; creating household assets, and increasing the standard of living to a great extent in the study areas. It is somewhat difficult to assess the socio-economic impacts of PTOS/HSRT on the livelihoods of service providers because many factors may also be able to contribute to uplift their standard of living. The socio-economic impacts of PTOS/HSRT on the livelihoods of service providers are discussed in the following sections.

11.1 Impact on land holdings:

Table 30 shows that the land holding size of the service providers has been increased to some extent along with different land categories after having PTOS/HSRT. Irrespective of providers' categories, the average holding size was increased by 9.7%. Significant change was occurred in the mortgage-in land that might be due to the direct effect of PTOS/HSRT service. The amount of rented-in land was decreased by 2.9% and rented-out land was increased by 5.5% implying the economic up-liftmen of the service providers in the study areas.

Table 30: Change in farm size before and after ownership of PTOS/HSRT in the study area

(Fig .in ha)

Land category	N	After having PTOS/HSRT	Before having PTOS/HSRT	Mean difference	P(T<=t) value
1. Own land	51	2.392	2.347	0.045	0.9198
2. Rented in	14	0.381	0.392	-0.011	0.9571
3. Rented out	19	0.492	0.466	0.027	0.8600
4. Mortgage in	33	0.337	0.076	0.260***	0.0000
5. Mortgage out	14	0.310	0.183	0.127	0.2481
6. Homestead	53	0.136	0.114	0.022	0.2820
7. Orchard	39	0.112	0.085	0.027	0.3353
8. Pond	44	0.129	0.106	0.023	0.3742
Farm size	**53**	**2.685**	**2.472**	**0.212** (9.7)	0.6104

Note: *** indicates significant at 1% level.
Figure in the parenthesis indicates percent increased over pre-ownership period.

11.2 Impact on livestock resources:

Due to the increased income of the service providers that earned from renting out PTOS/HSRT service, the most livestock and poultry resources were increased during post-ownership period. Remarkable decrease was found in the quantity of bullocks, but significant increase was registered in the value of calves (which will be ultimately milking cows), goats and adult chickens (Table 31).

Table 31: Change in livestock resources before and after ownership of PTOS/HSRT

Livestock and poultry	N	After having PTOS/HSRT		Before having PTOS/HSRT		Mean difference	
		Quantity	Value (Tk)	Quantity	Value (Tk)	Quantity	Value (Tk)
1. Bull/Ox	24	0.93	11691	1.52	13122	-0.59***	-1431
2. Cow	48	1.83	26669	1.56	21792	0.27	4877
3. Calves	40	1.33	9500	1.00	4095	0.33	5405***
4. Goat	33	3.48	5979	1.91	2218	1.57	3761***
5. Duck (Adult)	36	6.81	818	3.28	432	3.53	386
6. Chicken (Adult)	39	8.46	1204	6.64	793	1.82	411*
All types		22.84	55861	15.91	42452	6.93 (30.34)	13409 (24.0)

Note: *** and * indicate significant at 1% and 10% level, respectively.
Figures in the parentheses indicate percent increased over pre-ownership period.

11.3 Impact on household income:

The principal components of household income of the service providers were crop farming, service, farm machinery, business, and livestock and poultry farming. Table 32 shows the remarkable positive impact of PTOS/HSRT on the annual income of the service providers in the study areas. The annual household income was significantly increased by 50.4% during post-ownership period. The percent increase in income was found to be highest in case of farm machineries followed by livestock rearing and crop production. The service providers earned 19% of total income form PTOS/HSRT. They stated that it could be possible for them to buy other farm machineries like PT, STW, and thresher by the income received from PTOS/HSRT.

Table 32: Change in yearly household income before and after ownership of PTOS/HSRT

Income source	N	After having PTOS/HSRT	Before having PTOS/HSRT	Mean difference	P(T<=t) value
1. Crop production	53	236460 (34)	179933 (53)	56527*	0.0732
2. Service	15	140703 (20)	80933 (24)	59770	0.2889
3. Business	13	51846 (8)	41615 (12)	10231	0.4430
4. Livestock	40	18672 (3)	10097 (3)	8575***	0.0077
5. Fruit sale	6	7767 (1)	7300 (2)	467	0.9592
6. Farm machinery					
PTOS/HSRT	53	130510 (19)	0	130510	-
PT	36	44833 (7)	8194 (2)	36639***	0.0000
STW	35	11929 (2)	2943 (1)	8986***	0.0000
Thresher	19	44579 (6)	9737 (3)	34842*	0.0615
Total (Tk/yr)	53	687299 (100)	340752 (100)	216037***	0.0019

Note: *** and * indicate significant at 1% and 10% level, respectively.
Figures within parentheses are the percentages of total income.

11.4 Impact on farm equipment:

Increasing the household assets is closely related to the financial condition of the service providers of PTOS/HSRT. Renting out of PTOS service in the study areas has boosted up their asset position to a great extent. Table 33 revealed that the total quantity and value of farm equipment was increased by 16.6% and 70.5% respectively during post-ownership period of PTOS/HSRT. Most service providers mentioned that they purchased modern farm equipment like PT, STW, thresher, and sprayer by the income that earned from renting out of PTOS/HSRT service. That's why the highest and significant increases were apparent both in the number and value of STW, HTW, thresher, and sprayer.

Besides, the number of wooden plough decreased with the increase in the use of PT and PTOS/HSRT (Table 33).

Table 33: Change in farm equipment before and after ownership of PTOS/HSRT

Farm equipment	N	After having PTOS/HSRT		Before having PTOS/HSRT		Mean difference	
		Quantity	Value	Quantity	Value	Quantity	Value
1. PTOS/HSRT	48	1.02	81,590	0	0	1.02	81590***
2. Power tiller	25	1.00	54,760	0.64	35,620	0.36	19140*
3. STW	49	1.08	15,106	0.65	8,551	0.43***	6555*
4. HTW	53	1.28	7,404	0.89	4,726	0.39***	2678***
5. Sprayer	23	1.13	2,355	0.65	527	0.48***	1828
6. Thresher	22	1.14	32,414	0.50	5,732	0.64**	26682***
7. Wooden plough	27	0.19	52	1.44	743	-1.25***	-691***
8. Ladder	50	1.36	372	1.40	403	-0.04	-31
9. Spade	51	1.98	439	1.96	424	0.02	15
10. Sickle	51	6.20	761	5.75	598	0.45	163
11. Others	18	2.39	664	1.78	414	0.61	250
Total		18.77	195,917	15.66	57,738	3.11 (16.57)	138179 (70.53)

Note: ***, ** and * indicate significant at 1%, 5% and 10% level, respectively.
Figures in the parentheses indicate percent increased over pre-ownership period.

11.5 Impact on household assets:

Due to increased income, the housing status of all service providers of PTOS/HSRT has improved to a great extent. They have made remarkable improvements in their dwelling houses and kitchens during post-ownership period. Table 34 revealed that the number and value of *semi-pacca* building were significantly increased by 70.4% and 40.8% respectively during post-ownership period. On the contrary, the numbers of *Katcha-pacca* and *Katcha* houses decreased by 3.6% and 11.1% respectively. Remarkable improvements were also found in the number and value of both *semi-pacca* and *Katcha-pacca* kitchen. Most sample service providers had to construct more number of valuable storehouses due to increase in both crop production and household assets.

Table 34: Change in house types before and after ownership of PTOS/HSRT

House type	N	After having PTOS/HSRT		Before having PTOS/HSRT		Mean difference	
		Quantity	Value	Quantity	Value	Quantity	Value
1. Dwelling house		**7.07**	**529128**	**5.86**	**218224**	**1.21**	**310904**
Pacca[1]	4	1.75	202500	1.00	10000	0.75	192500
Semi-pacca[2]	42	2.40	236310	1.69	139929	0.71**	96381**
Katcha-pacca[3]	19	1.32	49318	1.37	40895	-0.05	8423
Katcha[4]	5	1.60	41000	1.80	27400	-0.20	13600
2. Kitchen		**3.28**	**93029**	**2.81**	**69319**	**0.47**	**23710**
Pacca	2	1.00	50000	1.00	50000	0	0
Semi-pacca	19	1.11	29000	0.84	13968	0.27**	15032**
Katcha-pacca	35	1.17	14029	0.97	5351	0.20	8678**
3. Other houses		**3.66**	**58656**	**3.14**	**43600**	**0.52**	**15056**
Cow shed	43	1.12	26988	1.10	18290	0.02	8698
Poultry shed	25	1.44	1768	1.24	1510	0.20	258
Storehouse	10	1.10	29900	0.80	23800	0.30***	6100

Note: [1] House with concrete roof and brick wall.
[2] House with corrugated iron (CI) sheet roof and brick wall.
[3] House with CI sheet roof and thrashed bamboo/jute stick/straw wall.
[4] House with straw roof and thrashed bamboo/jute stick/straw wall.
***, ** and * indicate significant at 1%, 5% and 10% level, respectively.

Providing PTOS/HSRT service has incredible impact in increasing the household assets in the study areas. Table 35 shows the comparative scenarios of the household asset positions of PTOS/HSRT service providers. The quantity and quality (in terms of value) of different types of furniture, modern amenities and other household assets of the service providers were significantly increased after having PTOS/HSRT. However, no change was made in the quantity and quality of *Chowki*, radio and boat in the study areas (Table 35).

Table 35: Change in household assets before and after ownership of PTOS/HSRT

Household assets	N	After having PTOS/HSRT		Before having PTOS/HSRT		Mean difference	
		Quantity	Value (Tk)	Quantity	Value (Tk)	Quantity	Value (Tk)
1. Furniture		**27.35**	**57,592**	**14.12**	**23,944**	**13.23**	**33648**
Cot	38	3.16	24,066	1.37	9,408	1.79***	14658***
Chowki[1]	50	3.18	3,942	2.88	3,912	0.30	30
Almirah	36	1.64	9,500	0.72	3,819	0.92***	5681***
Dressing table	25	1.56	5,544	0.24	1,000	1.32***	4544***
Tables	53	2.79	3,104	1.34	1,340	1.45***	1764***
Chairs	52	5.75	2,578	2.90	1,099	2.85***	1479***
Bench	36	1.19	785	0.89	538	0.30*	247**
Dress-stand	48	2.75	2,543	1.27	1,115	1.48***	1428***
Basket (large)	42	2.26	4,802	1.10	1,429	1.16***	3373***
Tool[2]	41	3.07	728	1.41	284	1.66***	444***
2. Modern amenities		**12.98**	**120,376**	**5.75**	**26,509**	**7.23**	**93867**
Mobile phone	47	1.81	7,569	0.15	543	1.66***	7026***
Motor cycle	14	1.14	95,786	0.29	19,643	0.85***	76143***
Television	35	1.31	11,589	0.49	3,397	0.82***	8192***
Cassette player	24	0.92	2,119	0.50	1,313	0.42***	806*
Radio	32	0.88	352	0.88	352	0	0
Wrist watch	41	2.49	1,390	1.39	599	1.10**	791***
Table/wall clock	45	1.91	573	0.78	228	1.13***	345***
Torch light[3]	48	2.52	998	1.27	434	1.25***	564***
3. Other assets		**3.68**	**18,892**	**2.74**	**14,927**	**0.94**	**3965**
Bicycle	47	1.79	6,004	1.23	3,574	0.56**	2430***
Rickshaw/van	26	0.92	3,312	0.54	1,777	0.38***	1535***
Boat	33	0.97	9,576	0.97	9,576	0	0

[1]a four legged wooden bedstead; [2]a wooden seat without a back for one person; [3]a light to be carried in the hand
Note: ***, ** and * indicate significant at 1%, 5% and 10% level, respectively.

11.6 Impact on liabilities:

The service providers of PTOS/HSRT were reported to be received loan from commercial bank, cooperative society, and local NGOs and borrowed money from moneylender, relatives, and many other sources for various purpose. Table 36 revealed that the average amount of loan received during PTOS/HSRT ownership period was about 34% higher than that of pre-ownership period that might be due to purchase of PTOS/HSRT and related accessories. This scenario also clearly indicates their higher access to the institutional credit facility in study areas.

Table 36: Change in liability position after ownership of PTOS/HSRT

Source of credit	N	After having PTOS/HSRT	Before having PTOS/HSRT	Mean difference	P(T<=t) value
1. Commercial bank	22	28,591	19,273	9,318	0.3037
2. Cooperative society	1	5,000	0	5,000	-
3. Local NGO	9	50,667	33,000	17,667	0.6570
4. Moneylender	2	17,500	27,500	-10,000	0.7788
5. Relatives	3	8,333	1,667	6,666	0.2522
6. Others	2	20,000	5,000	15,000	0.2048
All sources		**21,682**	**14,407**	**7,275**	

11.7 Impact on food intake:

Due to increased income that earned from renting out PTOS/HSRT service to others, the frequency and quality of food intake were significantly increased in the study areas. One of the highest improvements was reported in the case of weekly intake of milk, egg, and meat. Fish and vegetable intake also increased remarkably (Table 37).

Table 37: Change in food intake pattern after ownership of PTOS/HSRT

Food intake pattern	N	Frequency of food intake		Mean difference	P(T<=t) value
		After having PTOS/HSRT	Before having PTOS/HSRT		
1. Food intake (times/day)	53	3.32 (5)	3.15	0.17**	0.0400
2. Fish intake (time/week)	53	5.00 (25)	3.75	1.25***	0.0000
3. Meat intake (time/month)	51	3.10 (30)	2.18	0.92**	0.0507
4. Egg intake (time/week)	52	3.10 (37)	1.97	1.13***	0.0000
5. Milk intake (time/week)	53	5.79 (48)	3.02	2.77***	0.0000
6. Vegetable intake (kg/week)	53	10.94 (28)	7.91	3.03***	0.0043

Note: ***, ** and * indicate significant at 1%, 5% and 10% level, respectively.
Figures within parentheses indicate percent increase over pre-ownership period

11.8 Impact on overall livelihood status:

The overall standard of living social status of the service providers of PTOS/HSRT has been improved remarkably. It can be seen from Table 35 that irrespective of service providers' category, more than 94% of respondents used safe drinking water from Hand Tube-well and use sanitary toilet, and about 19% extra households get connection of electricity at their residences. Awareness development was another positive impact that was found in the service providers during post-ownership period. It was reported that the awareness of service providers regarding contraceptive use, sending children to school, and consultation with MBBS doctor was increased (6-19%) to some extent. Furthermore, better economic standing enabled them to buy more costly new clothes for several social and religious events. It revealed that more than 49% service providers were the members of local level cooperative society in the study areas. This implies that nearly 21% additional service providers have shown interest to become member of cooperative society after having PTOS/HSRT (Table 38).

Table 38: Increase in livelihood status before and after ownership of PTOS

Livelihood criteria	% responses		% increased
	After having PTOS/HSRT	Before having PTOS/HSRT	
Sample size (N)	*53*	*53*	*53*
1. Using tube well water	94.3	83.0	11.3*
2. Using sanitary toilet	94.3	69.8	24.5***
3. Using electricity	56.6	37.7	18.9*
4. Adopting contraceptive method	56.6	45.3	11.3*
5. Sending children to school	88.7	69.8	18.9*
6. Consultation with MBBS doctor	94.3	88.7	5.7
7. Buying new cloths in religious festivals	92.5	81.1	11.3*
8. Offering gifts in social events	94.3	83.0	11.3*
9. Membership with cooperative society	49.1	28.3	20.8**

12. FACILITIES NEED TO INCREASE PTOS/HSRT USE AT FARM LEVEL

12.1 Farmers' opinion:

The sample farmers mentioned some facilities that need to be created for them to increase the use of PTOS/HSRT in the near future. All of their demanded needs are displayed in Table 39. Forty eight percent of total sample farmers suggested that necessary steps should be taken to make PTOS/HSRT and spares available in the study areas. To make it available, about 38% farmers suggested for providing soft loan with low interest to the enthusiastic service providers for purchasing PTOS/HSRT, and the loan recovery system should be monthly installment basis. Some PTOS/HSRT owner cum farmers also argued that the price of PTOS/HSRT is high and they suggested for giving price subsidy on it. Service provider cum farmer demanded vigorous training on repair, operation and maintenance of PTOS/HSRT so that they can easily handle the problems. Some of the respondents requested to concerned engineers to create riding facility and make it in such a way that they can sow all kinds of seeds with PTOS/HSRT (Table 39).

Table 39: Facilities demanded by PTOS/HSRT and PT farmers for increasing the use of PTOS

Type of facilities	% responses		
	Rajbari district *(n=300)*	Dinajpur district *(n=110)*	All districts *(n=410)*
1. PTOS/HSRT should be available during peak season	45.0	56.4	48.0
2. Provide soft loan for buying PTOS/HSRT	36.7	40.9	37.8
3. PTOS price should be reduced	14.3	9.1	12.9
4. Spare parts should be available in peak period	18.3	14.5	17.3
5. Provide training on repair, operation and maintenance of PTOS/HSRT	17.3	13.6	16.3
6. Create riding facility to PTOS/HSRT	15.0	8.2	13.2
7. Create facility to sow all kinds of seed	9.3	6.4	8.5
8. Steps should be taken to encourage farmer	5.0	9.1	6.1
9. Others	8.3	5.5	6.8

12.2 Service providers' opinion:

The service providers of the study areas mentioned different ways and means for increasing the use of PTOS/HSRT in crop cultivation. About 74% of total service providers suggested that necessary steps should be taken to provide soft loan with easy

terms and conditions to the enthusiastic service providers against PTOS/HSRT purchase and the loan recovery system maybe monthly installment basis. Knowledge on repair, operation and maintenance is important for PTOS/HSRT driver to handle the problems, but they have inadequate formal training on it at all that often create problems. Hence a good number of service providers opined that program should be maintained to provide training on repair, operation and maintenance of the PTOS/HSRT for the service providers and operators. More than forty three percent service providers thought that the motivational activities should be carried out through publicity, demonstrations in the new areas, etc for expansion of PTOS/HSRT uses. Some of the respondents requested to concerned engineers to create riding facility. Some cooperative societies in the study areas were opined to be performed better in credit operations. For this reason, 32.1% of the PTOS/HSRT owners preferred cooperative society as loan disbursing agent for buying PTOS/HSRT. The other suggestions were made by the service providers to make available spare parts of the PTOS/HSRT at their nearest level; fuel and oil price should be reduced or subsidized; PTOS/HSRT should be supplied with subsidized price arrange to provide soft loan from NGOs, bank and CIMMYT (Table 40).

Table 40: Facilities need to be created for increasing the use of PTOS at farm level

Type of facilities	Responses *(N = 53)*	
	Number	%
1. Provide soft loan through bank/NGO for buying PTOS/HSRT	39	73.6
2. Provide training on repair, operation and maintenance for PTOS/HSRT	32	60.4
3. Steps should be taken to encourage farmer	23	43.4
4. Create riding facility to PTOS/HSRT	20	37.7
5. PTOS/HSRT should be supplied through cooperative society	17	32.1
6. Others*	10	18.9

* Make spare parts available; reduce fuel price; supply PTOS/HSRT with subsidized price through CYMMIT

13. CONCLUSION AND POLICY IMPLICATIONS

13.1 Conclusion:

The study has been conducted to find out the adoption status of PTOS/HSRT; the economic benefit of PTOS/HSRT on crop production; and the impacts of PTOS/HSRT on service providers' livelihoods. The study revealed that PTOS/HSRT is being largely used in the study areas to plant jute, wheat, sesame, mustard, lentil, onion, garlic, rice, and many other crops round the year. The increasing trends of PTOS/HSRT number, user, and land preparation area are much encouraging and higher in Rajbari district compared to Dinajpur. Most PTOS/HSRT service providers show negative attitude to plant seeds with PTOS as it time consuming, need extra attention, etc. Besides, majority of the farmers have very low confidence on PTOS/HSRT for sowing seeds rather than broadcasting because they can not see seed placement as it is placed at the depth of 2-3 cm below the surface level. Most of the Rajbari district farmers used two pass and Dinajpur district farmers used one pass to prepare land for cultivation. The peak period of PTOS/HSRT ranged from mid-October to mid-January, whereas the periods ranged from mid-August to mid-October and mid-May to mid-June are treated as lean period. PTOS/HSRT has strong and self demonstration quality that easily influenced farmers to use it. Farmers are highly motivated by neighbors to adopt PTOS/HSRT followed by BARI and CIMMYT scientists. Family members and extension personnel also play important role in adopting PTOS/HSRT.

The use of PTOS/HSRT at farm level has created a tremendous impact on farmers' income through crop production. Its use ensures higher crop yield and income for the farmers. The study reveals that the use of PTOS/HSRT has saved land preparation costs 16.98%, 18.55%, 30.67%, and 30.41% for wheat, jute, onion, and mungbean cultivation respectively. Besides, PTOS has saved 15.06% and 25.37% costs of seed for wheat and jute production, respectively. The onion seedlings incur 22.14% higher costs due to use higher number of seedling per unit area. The productivity, gross margin, net income, and BCR of different crops are found to be significantly higher for PTOS/HSRT using farmers compared to PT farmers. The increased crop yields and net incomes realized from different crop productions range from 16.07% to 18.47% and 22.94% to 46.31%, respectively. The farmers with PTOS/HSRT technology receive 17.9% higher gross return per hectare than PT using farmers. Due to its versatile use, 88% adopters want to increase the use of PTOS/HSRT in the next year with an area of 0.254 ha.

Providing PTOS/HSRT service at farm level is found to be highly remunerative. A service provider has received net income ranges from Tk. 20,530 to Tk. 2,01,905 with an average income of Tk. 81,003 per year. The study reveals that PTOS/HSRT has made a tremendous improvement in the livelihoods of its service providers in the study areas. The service providers have experienced a considerable increase in their land holdings (9.7%), annual income (31.34%), livestock resources (24%), farm equipment (70.53%), household assets position (21% to 78%), and dwelling houses (58.75%). The increased income of beneficiaries are mostly spent on farm machinery, nutritious food, cloths, health care, education expenses and making of houses that indicate higher standard of living to some extent, compared to pre PTOS/HSRT service period. It is also found that PTOS/HSRT is environment friendly since it can save 40% of fuel per hectare per year and emission of 43% less CO_2 into the atmosphere.

The service providers have stated few minor problems regarding PTOS/HSRT service which are driving by walking, roller jam, and lower depth in cultivation. The other stated problems are higher price of fuel and oil, non-availability and higher price of spare parts, and the scarcity of trained driver in the study areas.

13.2 Policy implications:

Some of the problems are associated with PTOS/HSRT adoption and that could be overcome if financial support and technical assistance are made available by the foreign and government of Bangladesh support project. This support could be channeled into some areas, i.e., awareness creation, credit support for service providers, providing support to local manufacturers for manufacturing and marketing the PTOS/HSRT and spare parts. Moreover, training for repair and maintenance mechanic, and operators is highly required. Demonstration activities should be strengthening in the new areas with new crops.

Further more, research work should be carried out to improve the machine with riding facilities, adding fertilizers application system with existing PTOS/HSRT that will improve fertilizer uses efficiencies. Long-term soil health related experiments should be undertaken to see the implications of the PTOS/HSRT use. Agronomic research also should be carried out to assess seed rate of different crops, fertilizer rate, planting depth, water management, weed management, line spacing, crop management, etc. All varieties might not perform well in this system, thus, varietals screening program also be carried out to identify best varieties of this system.

14. REFERENCES

Alam, M.M.; Sattar, M.A.; Faruque, M.O.; Hassan, M.S.; and Chowdhury, M.G.R. 2007. Manufacturing of agricultural machinery: Its problems, prospects and quality assurance. Proceedings of the National Workshop on *Strengthening Agricultural Mechanization: Policies and implementation strategies in Bangladesh* held at Dhaka on 11 June, 2007.

Barton, D. 2000. Options for farm power usein primary cultivationon small farms: Summary of main findings. Journal of *Agricultural Machinery and Mechanization*, 4(1): 1-4, 2000.

Compbell, M.J. (ed.) 1990. New Technology and Rural Development: The Social Impact. Routledge, London and New York.

Duft, B. 1986. Some consequences of agricultural mechanization in Philippines, Thailand and Indonesia. In: Small Farm Equipment for Developing Countries. Proceedings of the international conference on small farm equipment for developing countries.

Gill, G.J. 1984. Tractorization and rural employment in Bangladesh. In: Farm Power and Employment in Asia: Performance and Prospects. Proceedings of a regional seminar held at the Agrarian Research and Training Institute, Colombo, Srilanka. October 25-29, 1982. ADC, Bangkok.

Grace, P R. 2003. Rice-Wheat System and Climatic Change. Addressing Resource Conservation Issues in Rice-Wheat Systems of South Asia: A Resource Book. Rice-Wheat Consortium for the Indo-Gangetic Plains - International Maize and Wheat Improvement Center, New Delhi, PP. 63-67

Hatfield, J.L. and Karlen, D.L. 1992. Sustainable Agriculture Systems. CRC Press, Boca Raton. F.L

Haque, M.E., Hossain, M.I, Wohab, M.A., Sayre, K.D., Bell, R.W., Hossain, M.I. and Timsina, J. 2008. Agricultural Mechanization in Bangladesh and Conservation Agriculture: The Opportunities, Priorities, Practices and Possibilities. Forth International Conference of Conservation Agriculture. Forthcoming. February 2009, New Delhi, India.

Hossain, M I; Mondal, S N; Sarker, K K; Roy, K C and Haque, M E. 2008. Adoption of power tiller operated seeder in rice-wheat cropping pattern. In: Annual Report 2008, Farm Machinery and Post-harvest Process Engineering Division, BARI, Gazipur. P.39-44.

Islam, M.S. 2000. Socio-economic impacts of power tiller adoption on small farming in Bangladesh. J. of Agril. Mach. & Mech. 4(1): 77-85.

Jabbar, M.A., Bhuiyan, M.S.R. and Bari, A.K.M. 1983. Causes and consequences of power tiller utilization in two areas of Bangladesh. In: Consequences of Small Farm Mechanization, IRRI, Philippines.

Mannan, M. A. 2001. Farm and Rural Labour in Bangladesh: A Review. Research report, Bangladesh Institute of Development Studies, Agargaon, Dhaka.

Miah, M.A.M; Islam, M.S. and Miah, M.T.H. (2002). Socio-economic impacts of farm mechanisation on the livelihoods of rural labourers in Bangladesh. *Journal of Farm Economy*, 12: 147-162.

Miah, T.H. 2000. Economic impacts of using power tillers and draught animals for primary cultivation of small farms in Bangladesh. J. of Agril. Mach. & Mech. 4(1): 69-75.

Rahman, M. M. 1998. An economic study of multiple use of power tillers in an area of Mymensingh. Unpublished MS thesis, Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh.

Sayre, K.D. and P. Hoobs (2003). Raised Bed System of Cultivation for Irrigated Production Condition. Bed planting course, CIMMYT, Mexico.

15. APPENDIX TABLES

Table 1: Usages pattern of PTOS throughout the year

Time period	N	Average use (Hour/month/PTOS)		
		Minimum	Maximum	Mean
1. Mid March – Mid April	40	14	360	111.05
2. Mid April – Mid May	30	6	300	87.20
3. Mid May – Mid June	12	8	60	36.00
4. Mid June – Mid July	14	9	360	87.98
5. Mid July – Mid August	12	8	300	98.17
6. Mid August – Mid September	5	20	45	29.80
7. Mid September – Mid October	4	36	60	50.25
8. Mid October – Mid November	49	10	660	233.41
9. Mid November – Mid December	52	18	700	269.77
10. Mid December – Mid January	49	15	600	278.04
11. Mid January – Mid February	38	10	480	135.53
12. Mid February – Mid March	30	7	140	70.33

Table 2: Descriptive statistics of variables included in Probit model

Variables	N	Minimum	Maximum	Mean	Standard deviation
Age	410	17	80	38.64146	13.16737
Education	410	0	17	7.595122	3.393792
HH income	410	9500	1006800	213252.6	156032.3
Farm size (ha)	410	-88	3020	402.2741	323.9934
Family influence	410	0	1	.095122	.2937417
Farmers' influence	410	0	4	1.426829	1.695892
Scientist's influence	410	0	4	1.563415	1.842749
Extension contact	410	0	48	14.00732	6.419518

Table 3: Descriptive statistics of variables included in Cobb-Douglas production function

Variables	**N**	**Minimum**	**Maximum**	**Mean**	**SD value**
Gross income (Tk/ha)	410	22230	389212	107784	38545
Land preparation (Tk/ha)	410	371	12350	4212	1658
Cost of seed (Tk/ha)	410	40	15718	5474	4476
Cost of labour (Tk/ha)	410	3582	31324	13137	7723
Cost of fertilizers (Tk/ha)	410	0	20563	4296	3208
Cost of manures (Tk/ha)	410	0	12350	942	1552
Cost of pesticides (Tk/ha)	410	0	4117	276	612
Cost of irrigation (Tk/ha)	410	0	28068	3806	2550