Agricultural Technology Adoption and Land Productivity: Evidence from the Rice-Prawn Gher Farming System in Bangladesh

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ABSTRACT

Rice-prawn gher (RPG) farming system is an indigenous agricultural technology solely developed by farmers since mid 1980s. The present study aims to estimate the land productivity of modern varieties (MV) paddy production under RPG and (year-round modern varieties) YRMV paddy farming systems in the southwest Bangladesh. The RPG farming system has significant impacts on inputs used in MV *boro* paddy production. The findings of the study indicate that more chemical fertilizers were used in per ha MV *boro* paddy production under YRMV paddy farming in comparison with RPG farming. Similarly, per ha cost of irrigation, pesticides and land preparation were also higher in MV *boro* paddy production under YRMV paddy farming system compared to RPG farming system. The inputs usage for MV *boro* paddy production under two farming systems showed statistically significant difference with each others. Although fewer inputs were being used in MV *boro* paddy production under RPG farming system, yield was higher (statistically significant) than YRP MV paddy farming system. Therefore, it could be concluded that land productivity of MV paddy production under RPG farming system was significantly higher than YRMV paddy farming system. The TFP of MV *boro* paddy production was higher in RPG farming system compared to YRMV paddy farming system. Moreover, the TFP varied widely within the farms between the two farming systems.

Keywords: Rice-prawn gher farming, year-round MV paddy farming, land productivity

1. INTRODUCTION

Rice-prawn gher (RGP) farming is an indigenous technology which is a combined form of aquaculture and agriculture. The term ***"rice-prawn gher"*** refers to a modification of paddy field that has been used for prawn and MV paddy cultivation. The mid field (locally known as *chatal*) of gher is surrounded by high wide dikes and canals that lies the periphery of the dikes. The whole land of gher is filled up with rain-water from June to December and resemble to a pond and during this time, farmers cultivate prawn (*Macrobrachium rosenbergii*) and fishes. The entire land becomes dry naturally from January to April except canals. The canals retain sufficient water for MV *boro* paddy during this time.

Prior to the RPG farming, the southwest region experienced a period of severe environmental change during 1960s and 1980s because of the construction of embankments and polders that caused permanent waterlog and increased saline intrusion and the farmers were not able to produce any agricultural crops (Kendrick, 1994). After the introduction of RPG farming system, the cropping patterns have changed. Now the farmers are producing prawn and MV paddy in the RPG farming system throughout the year. Under the RPG farming system, farmers apply various combinations of feeds (for examples- meat of mud snail, fishmeal, oilcakes, broken maize and rice, husk of wheat and rice, pulses etc) to gher plots during the prawn production. These various feeds change the availability of soil nutrients. The main reason is that the prawn and carp fishes do not eat the entire feed supplied and the leftover feed makes the paddy field fertile and the paddy crop takes necessary nutrients from the fertile field. In addition to this, some aquatic habitats are grown during the prawn production and these aquatic habitats are used as composed manure to paddy production under RPG farming system. As a result, comparatively lower inputs used per unit MV *boro* paddy production under RPG farming system compared to other parts of Bangladesh.

There are a few studies that focus on the impacts of RPG farming on labor demand (Barmon et al. 2004) and household income (Barmon et al. 2004a; 2004b), and the impact of shrimp gher farming on the environment (Asaduzamman et al. 1998; Nijera Kori 1996; and Bhattacharya et al. 1999) and ecology (Datta, 2001) in the coastal region in Bangladesh. However, land and total factor productivity (TFP) of MV paddy production between RPG and YRMV paddy farming have not been analyzed explicitly. Therefore, the present study analyzes land productivity of MV paddy production under RPG and YRMV paddy farming system. Moreover, the present study estimates TFP of MV paddy production between two farming systems.

2. METHODOLOGY OF THE STUDY

2.1 Farm Survey and Data Collection

To assess the impacts of the technologically advanced RPG farming system on land productivity of MV paddy, two contrasting villages- RPG farming system for Bilpabla in Khulna and YRMV paddy farming for Chanchra village in Jessore district were selected. Bilpabla village was selected purposely; because the people have vast experience of RPG farming system like other parts of Khulna district and they directly or indirectly depend on their daily livelihood on various gher-farming activities. On the hand, Chanchra village located in Jessore district was also purposely selected because the farmers cultivate MV paddy throughout the year. Moreover, the Jessore is neighboring of Khulna district. Ninety (90) RPG farmers and 100 YRMV paddy farmers were randomly selected. The farm survey was carried out during November 2006 based on the agricultural cropping year 2005.

2.2 Variable Measurement

Farmland is the main input for any agricultural crop production. The farmland input was measured in terms of hectare. As usual, about 60% land of total gher farming is used for MV paddy production under RPG farming system. Human labor includes both male and female labor used in MV paddy production in a crop calendar year. Two types of human labor used in MV paddy production- hired and family labor. The labor input was calculated in terms of work hours of male and female labor employed for different farm operations. In this study, labor was measured in terms of adult man-days of eight hours. The measurements of hired and family labor are as follows: (1) Hired labor: The existing wage rate of hired labor both for male and female was considered (table 4). (2) Family labor: Both the family supply male and female labor engaged in various activities of paddy production. However, the family labors were not engage in full time like hired labors. In addition, sometimes, the efficiency of family labor's work is not uniform like hired labor, even though, some family members' work efficiency is same to hired labor. The difference in the efficiency of labor has been taken into account by converting family labor into hired adult man-days. The other main inputs such as chemical fertilizer, irrigation, pesticides and seedling cost were considered in the existing market price in 2005-06 both for RPG and YRMV paddy farming. The main output of MV paddy farming was paddy grain was considered in term of volume (kg) both for RPG and YRMV paddy farming.

2.3 Analytical Method

Total Factor Productivity (TFP) is the ratio of aggregate output to the aggregate input. The TFP can be measured using the following formula

$$TFP_i = \frac{Y_i}{X_i}$$

Where, i indicate *boro*, *boro* and *aman* paddy under RPG and YRMV paddy farming, respectively.

Y indicates the aggregated output index per farm in terms of value and X indicates the aggregated input index per farm in terms of value. The ideal Fisher quantity indexes were used to aggregate inputs and output. The arithmetic mean of *boro* paddy production under RPG farming system was considered as baseline to calculate TFP of MV paddy production between two farming system.

2.4 Regression Analysis of Total Factor Productivity (TFP)

2.4.1 MV *boro* Paddy Production under RPG System

To estimate the effects of various quantitative and qualitative factors on the TFP of MV paddy under RPG and YRMV paddy farming, a multiple regression model was used on the combined data. The empirical model of the effect of a set of explanatory variables on the TFP is specified using the following linear relationship:

$$TFP_i = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \delta D_i + \mu_i$$

Here, TFP is the total factor productivity index of MV *boro* paddy production under RPG farming system. The farmer and farm specific variables such as the scale of farm size (X_1: ha), age of the farmer (X_2: year), education of head of the farm household (X_3: year), family size (X_4: number), weeding (X_5: number of weeding during the production period), plough (X_6: number), and dummy variable D_7 (dummy, 1 if the farmer change position of canals after few years, 0 otherwise) used as explanatory variables. Farm size (X_1) is an indicator of wealth of farmers that positively affect the crop yield as well as TFP (Polseon and Spencer, 1991; Ransom et. al. 2003). Therefore, it is hypothesized that the sign on this variable in the empirical model is positive. A farmer's age (X_2) can be either generate or erode confidence in crop production. In other words, with more experience, a farmer can become more or less risk-averse when taking decision regarding input use in crop production. Some studies found that younger farmers are more informative about farm production and they easily bear production risk (Kedebe et. al. 1990; Polseon and Spencer, 1991). The contradictory results were also found (Adesina et al., 1995; Ransom et. al. 2003). Thus, the expected sign on farmer's age may be positive or negative in the empirical model. Education increase farmer's ability and knowledge to crop production. An educated farmer is more informative and bears all types of production risk. Therefore, the expected sign on education (X_3) in the empirical model is positive. Large family size (X_4) or households able provide the necessary labor for timely land preparation, weeding, and harvesting. Moreover, the family labors easily involve in spraying insecticide, topdressing of fertilizer and irrigation activities that affects the paddy production yield. Thus it is hypothesized that family size (X_4) has positive affect on TFP. Weeding (X_5) is also important for high paddy yield. In RPG farming system, some farmers do not weed the paddy field at all or sometimes weed 1-2 times during the whole MV *boro* paddy production cycle. To see the impact of number of weeding (X_5) on yield as well as TFP, weeding (X_5) is included in the empirical model and the expected sign on weeding (X_5) is positive. Plough (X_6) is an important factor that affects the MV *boro* paddy yield widely in RPG farming system. In RPG farming system, some farming does not plough the mid field of gher during transplanting. If the farmer ploughs the mid paddy field of gher before transplanting, then all algae and weeds go down under soils that compose all and it use as fertilizer. Therefore, the number of plough (X_6) is included in the empirical model and the expected sign is positive. A dummy variable (X_7) is included in the empirical model to evaluate the change in the position of canals on paddy yield as well as TFP. As mentioned earlier, under the physical construction of RPG farming, the mid paddy fields are surrounded by canals. Recently some farmers are changing the position of canal for soil fertility for good prawn production as well as paddy production. As usual, prawn like hard soils in water rather than clay soils because clay soils create many unhygienic materials as well as gases. The farmers believe that these unhygienic materials and gases hinder the growth of prawn or sometimes create diseases for prawn. Even though the farmers clean and wash the canals ever year as routinely, the old canals are not suitable for good prawn production. Depend on this believe some farmers are changing canals after years of prawn production cycle. Therefore it hypothesized that the change in the position of canals has significant positive effect on TFP of MV *boro* paddy production in RPG farming system. β_i and δ are regression coefficients in the empirical model.

2.4.2 MV Paddy Production under YRMV Paddy Farming System

Like the empirical model of TFP in RPG farming, the multiple regression equations were used in order to find out the factors that affect the TFP of MV *boro* and *aman* paddy production under YRMV paddy farming system. The empirical model of TFP is as follows:

$$TFP_i = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \mu_i$$

Here TFP indicates total factor productivity index. The empirical model includes farm size (X_1: ha), age of the farmer (X_2: year), education of the head of the farm household (X_3: year), and family size or household size (X_4: number) as explanatory variables. The explanation and definition of the variables in this model are similar to the explanatory variables in the empirical model for the TFP of MV *boro* paddy production under RPG farming system. As the same farmer produce MV *boro* and *aman* paddy once a year, the same factors are considered for the TFP *boro* and *aman* paddy production in RMV paddy farming system. β_i and δ are regression coefficients in the empirical model.

2. CROPPING PATTERNS OF THE STUDY VILLAGE

The cropping pattern of the study villages is presented in figure 1. Before the advent of RPG farming in Bilpabla village, the farmers cultivated only local *aus* and broadcasting *aus* and *aman* paddy in swampland and transplanting *aman* (T. *aman*) paddy in the upper lands. The familiar broadcasting *aus* and *aman* paddy has almost disappeared mainly because of mainly siltation of inland rivers and canals, embankments of rivers, and environmental changes. The life cycle of broadcasting *aman* was longer than the broadcasting *aus* paddy though the sowing time was same for the both types of paddy. The sowing time of *aus* and *aman* paddy is in April/May and harvesting time is in August for broadcasting *aus* and December for broadcasting *aman*. The farmer sowed *aus* and *aman* seeds together in April/May because after June/July the whole area was go underwater due to heavy rain and at that times it was not possible to transplant *aman* (*T. Aman*). This production system of local *aus* and *aman* paddy together was locally known as "*Domuti*".

Figure 1. Cropping patterns of the study village	
Bilpabla village : RPG farming	Chanchra village : YRMV paddy farming
Before RPG farming: Broadcasting *aus* paddy: April-August; Broadcasting *aman* paddy: April-December	**Before green revolution:** Broadcasting *aus* paddy: April-August; Transplanting *aman* paddy: August-December
After RPG farming: Prawn production: May-December MV paddy production: January-April Vegetable production: January-December	**After green revolution:** MV *boro* paddy production: January-April MV *aman* paddy production: July-November

Under RPG farming, production period of prawn and fish starts from May/June to December/January, MV *boro* paddy from January to April and vegetable throughout the year. The farmers have also planted fruit trees (coconut, mango, guava, jackfruit, banana, papaya etc.) on the dikes. The cropping system of Chanchra village is also presented in figure 1. Farmers in Chanchra village usually practice YRMV paddy farming because the farms are located in relatively high altitude levels that are not possible to convert into RPG farming system. MV *boro* paddy is produced during January to April followed by local variety T. *aman* paddy during July to December.

5. RESULTS AND DISCUSSIONS

5.1 Input usage for MV Paddy Production under two Farming Systems

Chemical fertilizers, irrigation, land preparation equipments and seeds are the main inputs of MV paddy production. The main inputs used in MV paddy production under RPG and YRMV paddy farming in southwest Bangladesh are discussed in this section.

Farmers use various types of chemical fertilizers to enhance the soil fertility for maximum rice yield. Chemical fertilizers such as urea, triple super phosphate (TSP), muriate of potash (MP), gypsum, and zinc sulfate are commonly used in YRMV paddy production in Bangladesh. Similarly, the RPG farmers mainly apply urea, TSP, MP, and gypsum for MV *boro* paddy production. Usually the farmers do not use any chemical fertilizers except homestead manure and cow dung for local *aus* and T. *aman* paddy production. However, the farmers apply chemical fertilizers for MV *aman* paddy production. Application of chemical fertilizers for per hectare paddy production under two farming system is presented in table 1. The table shows, on an average, more chemical fertilizer used in per ha YRP production in Chanchra village compared to MV *boro* paddy production under RPG farming system in Bilpabla village. All the values of the t-statistics are statistically significant at 1% level. Even though very small of chemical fertilizers are needed for MV *aman* paddy production, the amount of fertilizers used in per ha *aman* paddy production were also higher than MV *boro* paddy production under RPG farming system and these were also statistically significant except TSP.

Table 1. Per hectare inputs use (kg) and input costs (Tk) in MV paddy production under two farming systems

Types of fertilizers	Farming systems			Ratio and t-statistic			
	RPG farming	YRMV paddy farming		Ratio	t-statistic	Ratio	t-statistic
	Boro Paddy (A)	*Boro* paddy (B)	*Aman* paddy (C)	(B/A)		(C/A)	
Urea (kg)	82.5	300.9	112.8	3.7	-19.86*	1.4	-4.19*
TSP (kg)	58.6	153.2	59.0	2.6	-12.45*	1.0	-0.08
MP (kg)	4.4	78.4	19.9	18.0	-22.25*	4.6	-7.97*
Gypsum (kg)	2.4	20.8	7.0	8.7	-3.27*	2.9	-1.96**
Fertilizers (Tk)	1,587	5,795	2,050	3.65	-19.89*	1.29	-3.55*
Irrigation (Tk)	1,724	5,439	207	3.15	-12.35*	0.12	17.79*
Pesticides (Tk)	1,615	2,040	1,575	1.26	-1.91***	0.98	0.18
Land preparation cost (Tk)	1,204	2,204	2,069	1.83	-19.08*	1.72	-15.65*

Source: Field survey, 2006.

Notes: (1) Sample sizes were RPG and YRMV paddy farming for 90 and 100, respectively.

(2) TSP and MP indicate Triple super phosphate and Muriate of potash, respectively.

(3) * and ** indicate statistically significant at 1% and 5% level, respectively.

5.2 Input Cost of MV Paddy Production between two Farming Systems

As comparatively higher inputs used in per ha MV paddy production in YRMV paddy farming system than RPG farming system, on an average, per ha input costs were also higher for YRMV paddy farming system. Average costs of chemical fertilizers, irrigation and pesticides for per ha MV *boro* paddy production under RPG farming system in Bilpabla village and YRMV paddy production in Chanchra village, their ratios and t-statistics are also presented in table 1. The table shows that on an average, per ha chemical fertilizers, irrigation and pesticides costs were higher in YRMV paddy farming in Chanchra village compared to MV *boro* paddy production under RPG farming system in Bilpabla village. Per ha cost of chemical fertilizers for MV *boro* paddy production under YRMV paddy farming system was more than three times higher than MV *boro* paddy production under RPG farming system. Similarly, per ha irrigation and pesticides costs were higher for MV *boro* paddy production in YRMV paddy farming than RPG farming. The table 1 also shows that within the YRMV paddy production, per ha costs of chemical fertilizers, irrigation and pesticides were higher MV *boro* paddy production compared to its counterparts MV *aman* paddy production. The main reason is that the MV *aman* is rainfed crop in Bangladesh and all the paddy field goes under water during the growth period of the crop.

The value of t-statistics indicated that all the input costs were significantly different (1% level of significance) with each others between the two farming systems.

5.3 Labor Input used in MV Paddy Production under two Farming Systems

As mentioned earlier that RPG and YRMV paddy farming are completely different in terms of management and production process. Therefore, per unit labor use is also different in two types of agricultural system. Barmon et al, [3] conducted a research on labor demand between RPG and YRMV *boro* and local *aman* paddy farming in the neighboring two study villages. In this section, only the comparison of labor uses in per ha MV *boro* paddy production was made. Per ha labor use and t-statistics are shown in table 2. The table shows that more hired male and female labors (statistically significant at 1% level) were used in per ha MV *boro* and *aman* paddy under YRMV paddy farming system compare to MV *boro* paddy production under RPG farming system. However, more family male labors were used in MV *boro* paddy production compared to YRMV paddy farming (statistically significant at 1% level).

Table 2. Per hectare labor used in MV paddy production under two farming systems

Farming systems	RPG farming	YRMV paddy farming		t-statistic	
	MV *boro* paddy	MV *boro* paddy	MV *aman* paddy	T_1	T_2
Hired labor :					
Male (man-day)	45	106	80	-24.36*	-14.43*
Female (man-day)	9	18	16	-5.47*	-4.18*
Family labor :					
Male (man-day)	39	12	13	7.75*	7.38*
Female (man-day)	16	5	5	5.90*	6.41*

Source: Field survey, 2006.

Notes: (1) One man-day is equal to 8 hours per day.

(2) T_1 indicates the t-statistic for *boro* paddy production between two farming systems.

(3) T_2 indicates the t-statistic for *boro* and *aman* paddy production between two farming syster

(4) * indicates statistically significant at 1% level.

5.4 Land Productivity of two Farming Systems

Land productivity mainly depends on irrigation facility, application of chemical fertilizers, varieties of seed and production environments. When MV paddy is produced under different farming systems, then production environment plays a significant role on land productivity. The farmers produced same variety of MV *boro* paddy under RPG and YRMV paddy farming systems, although production environment as well as farming systems was different.

Table 3. Per hectare grain yield of MV paddy under two farming systems

Particulars	Farming systems		Ratio	t-statistic
	RPG farming	YRMV paddy farming		
Boro paddy grain yield (kg)	5,237	4,791	1.09	9.37*
Aman paddy grain yield (kg)	Na	4,029	Na	Na

Source: Field survey, 2006.

Note: (1) * indicate statistically significant at 1% level.

As per ha yield is the main indicator of land productivity, per ha yield paddy grain was used as land productivity. Per ha yield of MV *boro* and *aman* paddy under two farming systems are presented in table 3 and shows that per ha yield of MV *boro* paddy grain was higher (statistically significant at 1% level) under RPG farming than YRMV paddy farming system. Per ha yield of MV *boro* paddy grain was also higher (statistically significant at 1% level) than that of MV *aman* paddy grain within the same YRMV paddy farming. In other words, land productivity was higher in MV *boro* paddy production under RPG farming in comparison with MV *boro* and *aman* paddy production under YRMV paddy farming.

6. INPUTS AND OUTPUTS INDEX FOR TFP MEASUREMENT

Calculating TFP requires inputs included in the input index are cultivated land, irrigation, pesticides, human labor, land preparation, seedling and chemical fertilizer. Paddy grain was the main output of paddy production. The quantities and prices of inputs and outputs used in MV paddy production under RPG and YRMV paddy farming system are presented in table 4.

6.1 Analysis of TFP for Paddy Production

The analysis of TFP for MV *boro* and *aman* paddy production under RPG and YRMV paddy farming system in presented in table 5. The figures in table show that on an average, the mean TFP for MV *boro* paddy was 0.88 widely varies from 0.33 to 1.71 and 0.73 ranges from 0.19 to 1.22, respectively, for RPG and YRMV paddy farming system. The mean TFP for MV *aman* paddy was 0.78 that lies from 0.32 to 1.23 under YRMV paddy farming. On an average, the TFP for MV *boro* paddy production under RPG farming system is higher than YRMV paddy farming. The values of coefficient of variation (CV) indicated that the TFP of MV paddy production widely varied within the farms between RPG and YRMV paddy farming systems. The main reasons were that prawn is the main output for RPG system and produce for export to earn foreign currency, and MV *boro* paddy produce for own family consumption throughout the year. Moreover, MV *boro* paddy is not profitable enterprise like prawn. As a result, farmers in RPG farming system, do not engage seriously in paddy production like prawn production. Similar experiences were also found in YRMV paddy farming village. As paddy is not profitable enterprises, the farmers in YRMV paddy farming village engage in other farm activities like fish culture throughout the year and produce paddy only for family home consumption. Some rich farmers in terms of large farm size maintain the paddy enterprise with hired labors. As a result, the TFP was positively related with farm size.

Table 4. Description, measurement and summary statistics of the variables (per farm basis)

Variables	Measurement	*Boro* (gher faming)		*Boro* (Year-round)		*Aman* (Year-round)	
		Mean	SD	Mean	SD	Mean	SD
Farmers' age	year	41.2	14.1	46.0	9.4	46.0	9.4
Farmers' education	year	6.3	3.7	4.8	4.7	4.8	4.7
Family size	No.	4.4	1.2	4.3	1.0	4.3	1.0
Workable male	No.	1.4	0.7	1.2	0.4	1.2	0.4
Workable female	No.	1.0	0.2	1.0	0.1	1.0	0.1
Farmland area	ha	0.51	0.43	0.63	0.53	0.63	0.53
Seedling cost	taka	847.6	753.5	897.2	763.7	685.9	630.7
Land preparation cost	taka	677.6	863.3	1392.0	1205.0	1321.0	1179.0
Irrigation cost	taka	1051.0	1233.0	3344.0	3221.0	116.0	194.7
Pesticides cost	taka	818.0	1379.0	1375.0	1295.0	1033.7	946.2
Chemical fertilizers:							
Urea	kg	40.4	41.8	188.6	162.3	69.0	61.6
Price (Urea)	taka/kg	7.0	0.0	7.0	0.0	7.0	0.0
TSP	kg	31.4	43.1	94.5	78.9	34.7	28.7
Price (TSP)	taka/kg	16.0	0.0	16.0	0.0	16.0	0.0
MP	kg	4.3	15.9	48.0	39.9	11.6	10.4
Price (MP)	taka/kg	2.0	5.1	15.0	0.0	15.0	0.0
Gypsum	kg	1.5	6.9	10.5	33.3	2.4	6.4
Price (gypsum)	taka/kg	0.3	0.9	0.5	1.1	0.4	1.0
Hired labor:							
Male labor	man-days	24.9	28.5	66.1	55.3	51.6	43.6
Wage rate	taka/day	120.0	0.0	90.0	0.0	90.0	0.0
Female labor	man-days	5.4	7.5	10.0	8.6	9.3	8.5
Wage rate	taka/day	90.0	0.0	60.0	0.0	70.0	0.0
Family labor:							
Male labor	man-days	12.3	4.9	5.1	2.1	5.8	2.3
Wage rate	taka/day	92.7	8.2	73.6	6.6	77.3	5.6
Female labor	man-days	4.9	3.2	1.9	1.1	1.7	0.8
Wage rate	taka/day	65.7	7.1	48.3	6.3	49.2	7.2
Output:							
Paddy grain	kg	2,685	2,383	3,051	2,599	2,534	2,080
Price	kg/taka	10.5	0.9	12.1	0.4	11.0	0.6

Note: (1) 1 US$ is equal to 69.78 taka (May, 2007)

Table 5. Descriptive statistics of total fator productivity (TFP)

Paddy Production	Mean TFP	SD	Min	Max	CV
Boro (RPG farming)	0.880	0.334	0.315	1.711	0.380
Boro (YRMV paddy farming)	0.730	0.185	0.344	1.215	0.254
Aman (YRMV paddy farming)	0.776	0.222	0.320	1.233	0.286

Note: SD and CV indicate standard deviation and co-efficient of variation, respectively.

6.2 Affecting Factors of Total Factor Productivity (TFP)

The coefficients of factors that affect the TFP of MV *boro* paddy production under RPG farming system, MV *boro* and *aman* paddy production in YRMV paddy farming are presented in table 6. The coefficients of farm area, ploughing and dummy variable for change in canal are positive and statistically significant at 1% level. This indicates that farmland, ploughing and change in canal were the main factor that affects significantly the TFP for MV *boro* paddy production under RPG farming system. However, the coefficients of other factors were not statistically significant but positive sign which indicates that farmers' age, education, family size and number of weeding have not significant contribution of TFP.

The coefficient of ploughing (0.080) is positive and statistically significant at 1% level which indicates that the ploughing has significant impact on TFP for MV *boro* paddy production under RPG farming system. As usual the paddy fields of YRMV paddy farming are ploughed 2-3 times before transplanting using power-tiller or bullock or tractor. But paddy fields of RPG farming system are not ploughed frequently before paddy transplanting. The main reasons are that after prawn harvesting the paddy fields (mid field of gher farming) is not dry enough for ploughing or sometimes the paddy field retain small amount of water which is also suitable for plantation. Moreover, soils of the mid fields become clay for transplanting because during prawn harvesting these soils are well mixed. Recently, a large number of paddy fields are cultivated before transplanting. Because, some aquatic habitats and various varieties of algae are grown on the bottom of gher farms during prawn production and these aquatic habitats and algae are go under clay by the harvesting mechanism of prawn. These aquatic habitats and algae are rotten smoothly due to ploughing before transplanting and make the land fertile for MV paddy production. Therefore, if the farmers plough the paddy field before transplanting the TFP for MV *boro* paddy will increase significantly in RPG farming system.

Table 6. Estimates of regression of total factor productivity (TFP)

Variables	*Boro* paddy (RPG)	*Boro* paddy (YRMV)	*Aman* paddy (YRMV)
Constant	0.31	0.50	0.45
	(2.77)*	(6.64)*	(5.17)*
Farm area (ha)	0.57445	0.264	0.314
	(11.82)*	(10.61)*	(10.94)*
Age (year)	0.0018	0.0007	0.0005
	(1.28)	(0.48)	(0.32)
Education (year)	0.001572	-0.0042	-0.0017
	(0.29)	(-1.52)	(-0.53)
Family size (no.)	0.00536	0.012	0.026
	(0.34)	(0.85)	(1.59)
Weeding (no.)	0.03645	-	-
	(1.40)	-	-
Ploughing (no.)	0.08073	-	-
	(1.82)*	-	-
Change canal	0.12466	-	-
	(2.90)*	-	-
R^2	0.77	0.57	0.60

Notes: (1) The figures in parentheses indicate t value.
(2) * indicate significant at 1% level.

The coefficient of dummy variable (0.125) is positive and statistically significant at 1% percent level, indicating that if the RPG farmer changes in the canals after few years, the TFP for MV *boro* paddy production will significantly increase. The main reason is that the changes in canals make the soils upside-down smoothly. In other words, the topsy-turvy of soils owing to canals change has significant impacts on land productivity that influence the MV *boro* paddy production under RPG farming system. At the early stage, the mid paddy field of gher farming system is surrounded by canals. Now, the farmers are changing the position of canals in mid paddy field because the changing the position of canals move the soils from one place to another in the paddy field. This movement and topsy-turvy of soils also make the land fertile that has significant influence on TFP for MV *boro* paddy production under RPG farming.

The coefficients of the farmers' age and education, family size are not statistically significant except farmland area for MV *boro* and *aman* paddy production under YRMV paddy farming. The coefficients of farmland area are statistically significant of TFP for MV *boro* in RPG farming system. This indicates that the scale of farmland has significant impact on TFP for RPG farming systems. The comparatively large farm size has significant impacts on TFP. The main reason was that the farmers of large farmland have used comparatively less labor (man-day/ha) for MV paddy production under RPG farming system. Because the farmers in RPG farming system produce prawn for export and cultivate MV *boro* paddy for own family consumption. They always care about prawn production. It was observed from field survey that the farmers who hold comparatively large farmland use more hired labor than family labors. The farmers of small farmland usually use more family labor than hired labor. As the farmers in large farmland use comparatively less labor (man-day/ha), the TFP index was positively correlated with scale. In other words, the TFP of MV *boro* paddy production was higher for comparatively higher for large farm sizes.

On the other hands, the farm size has also statistically significant impacts on TFP index both for MV *boro* and *aman* paddy production under YRMV paddy farming. Even though the farm size has significant impact on TFP index, the farmers in large farmland under YRMV paddy farming did not use comparatively less labor (man-day/ha) like the large farm of RPG farming system. However, some TFP indexes were found with positive correlation with farm size. Therefore, it may be concluded from the above analysis that agricultural farmland size plays an important role for TFP both for RPG and YRMV paddy farming in the study villages. Moreover, ploughing and change in the position of canals also have significant impacts on TFP for MV *boro* paddy production under RPG farming system.

7. CONCLUSIONS

RPG farming system is an indigenous agricultural technology solely developed by farmers since mid 1980s. The cropping pattern has changed from YRMV paddy farming to RPG farming system after the introduction of gher farming. The RPG farming system has significant impacts on land productivity for MV paddy production than YRMV paddy farming. The findings of the study indicate that more chemical fertilizers such as urea (72%), TSP (61%) MP (94%) and gypsum (88%) used in per ha MV *boro* paddy production under YRMV paddy farming compare to RPG farming. Similarly, per ha irrigation (61%), pesticides (26%) and land preparation (17%) cost were also higher in MV *boro* paddy production under YRMV paddy farming system compared to RPG farming system. Along with main inputs, more hired male labor also used in per ha MV *boro* paddy production under YRMV paddy farming compared to RPG farming. The total factor productivity for paddy production was higher in RPG farming system compared to YRMV paddy farming system. The TFP varied widely within the farms between the two farming systems. Therefore, it could be concluded that RPG farming system has increased the land productivity for MV paddy production and reduced input usage as well as costs for per ha MV *boro* paddy production compared to YRMV paddy production in Bangladesh.

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