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Research Article

Determinants and Impact of the Adoption of Improved Maize Management Practices: An Empirical Investigation on Bangladesh Agricultural Research Institute Developed Maize Sheller in Mymensingh District of Bangladesh

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Abstract

Adoption of new agricultural technologies is always at the center of policy interest in Bangladesh as it generates higher farm productivity and income for the farmers. Despite the visible benefits of many of the new agricultural technologies, including farm machinery and management practices, farmers either do not adopt them or it takes a long time to begin the adoption process and scaling up. The study was carried out to determine the impacts of adoption of Bangladesh Agricultural Research Institute (BARI) maize sheller on productivity and farm income in Mymensingh district. Primary data were collected from 41 adopters and 79 non-adopters of BARI maize sheller. Propensity score matching method was used to assess the impacts of BARI maize sheller adoption. It was found that the rate of adoption of BARI maize sheller was 26.73% at farm level. Probit model showed that experience in maize cultivation and training enhanced the adoption of BARI maize sheller. BARI maize sheller adoption on average increased maize productivity and farm income by 327.08 kg/ha and 34 to 65% respectively for adopters compared to non-adopters. Policy implications included more investment in training facilities from public and private agencies to sustain and increase the productivity and income of maize farmers. Modifying the training approach could provide opportunity to young maize farmers to increase their know-how. Various government and non-government organizations working in Bangladesh including Mymensingh district need to promote a rapid uptake and scaling up of BARI maize sheller.

Introduction

By 2050, the population of Bangladesh is expected to reach 215.4 million (Kabir et al., 2015). On the other hand, due to vulnerability of the country, the climate change presents a major risk to decline rice, wheat and maize yields by 32 to 62% by 2050 (Faisal, 2004). As a result, the consumption (demand) of staple cereals, including rice, wheat, maize, as well as fish and meat products is expected to increase dramatically in Bangladesh (Godfray and Garnett, 2014). To ensure cereal food security alone in 2050, more than a doubling of production is required (Tilman et al., 2011). This situation is complicated by the anticipated strain on cropland availability as every year agricultural land is decreased around @1% (80,000 hectares) per year, resulting in calls to intensify production on available land. The government is attaching special importance to intensive agricultural production and development. As agriculture is a leading source of income and employment in Bangladesh where more than 40.6% of the total population depends primarily on agriculture, and 13.32% of the Gross Domestic Product (GDP) comes from this sector (BBS, 2019). As part of this intensification and agricultural development, special initiatives have been taken to modernize agriculture. The Seventh Five-Year Plan focuses on activities related to expansion of modern agricultural technology, production of high value crops, increasing productivity through the use of agricultural machinery and increasing the real income of farming families. However, at the same time, rural to urban migration is increasing with the expansion of non-farm employment

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opportunities, causing seasonal rural labour shortages (Zhang et al., 2014). Within this evolving context there has been strong advocacy for agricultural machinery appropriate for farmers' small fields and resource base, and to enhance land productivity and encourage sustained agricultural intensification (FAO, 2008; Kienzle et al., 2013). To fulfil its aspirations advocacy for agricultural machinery and the demand of farm and farmers, BARI has developed some appropriate farm machinery suitable for fragmented land and small land holders. BARI has developed 38 numbers of agricultural machinery like high speed rotary tiller, seeder, bed planter, weeder, reaper, thresher, maize sheller, winnower, potato planter, harvester& grader, solar pump, hot water treatment plant for fruits and vegetables, etc. which can be used for the cultivation and processing of wheat, maize, potato, rice, pulses and vegetables.

However, maize is gaining importance in recent years as a promising crop aimed at boosting agricultural development and commercialization in Bangladesh. Maize possesses a wide genetic variability enabling it to grow successfully in any environment and in Bangladesh it is grown both in winter and summer time, although the former is the dominant pattern. Maize production and yield have experienced an explosive growth in Bangladesh in recent years. The cropped area of maize has increased from only 2,654 ha in 1972 to 400,639 ha in 2018; production from 2,249 t to 3,288,000 t; and yield from 0.85 t/ha to 8.21 t/ha during the same period. Maize has now positioned itself as the 1st among the cereals in terms of yield rate (8.21 t/ha) as compared to wheat (3.13 t/ha) and rice (3.12 t/ha) (BBS, 2019). The sequence of maize processing includes, harvesting, dehusking, shelling, winnowing, drying, bagging, and storage (Buliaminu, 2011). Maize shelling or simply maize threshing is the most important aspect of post-harvest operation of maize. Threshing or shelling is one of the most important crop processing operations to separate the grains from ear heads or the plants and prepare it for market and further processing to produce flour and fish and animal feed. Traditionally, dehusking and shelling of maize are carried out manually which involves a lot of drudgery. In Bangladesh, over 50% maize shelling is done by non-mechanized, non-standard shelling devices, resulting high percentage (often 7 - 8%) of broken kernels causes a lot of wastage in terms of quantity and quality (Milufarzana et al., 2015). Few studies including Alam and Momin (2009) had been done on the performance status of BARI maize sheller in Bangladesh. So far, none of them addresses the demanding issue of adoption status of maize sheller at farmers field. Therefore, this study has been undertaken to document the status of field level performance, using pattern, adoption, impact of selected BARI maize sheller and farmers' perception on BARI maize sheller.

Materials and Methods

Selection of the study areas, sample size and sampling technique

This study was conducted at Mymensingh district in Bangladesh. Purposive sampling technique was used to collect farm level data. Mymensingh district was purposively selected based on maize production potential and presence of BARI maize sheller technology interventions. Three upazillas namely Sadar, Nandail and Trishal upazilas were selected for BARI maize sheller adopter and non-adopter farmers. The villages of Borian, Begunbari, Bashati, Biarta and Sultanpur were purposively selected for adopters based on availability of BARI maize sheller where non-adopters shell their maize by hand were randomly selected from the respective upazilas. A total of 120 respondents were selected where 41 and 79 for BARI maize sheller adopter and non-adopter for the study.

Descriptive analysis

Descriptive statistics such frequencies, percentages, mean and standard deviations were used to analyze and compare the socioeconomic characteristics and institutional variables, between adopters and non-adopters of BARI maize sheller.

Profitability analysis

An attempt was made to estimate the detailed costs and returns of both user and non-user of BARI maize sheller in maize cultivation in study areas. The financial profitability of maize production of BARI maize sheller user and non-user was calculated using simple accounting procedures. Finally, the cost and return of maize using BARI maize sheller were compared with the respective cost and return of non-users.

Impact analysis

Maize productivity by using BARI maize sheller and farm household income have been used to estimate the impact of BARI maize sheller. Maize productivity is the amount of maize production generated by use of BARI maize sheller from one hectare of land, while farm income is the total income that received from the farm activities.

Econometric analysis

The probit regression model was used to estimate the determinants of adoption of BARI maize sheller in maize farming. After estimating the propensity scores, matching of observations from the treated and control groups was carried out based on their propensity scores. The impact of adoption of BARI maize sheller on productivity and income of farm households were estimated through the three different propensity score matching (PSM), i.e., nearest neighbour matching, kernel-based matching, and radius matching methods. The model was estimated using STATA version 14.

In social science studies, it is often not feasible to conduct a randomized controlled experiment for estimating the causal effect on intervention. For that selection bias becomes a problem since it is difficult to obtain a comparison group equivalent to the group of exposed or treated individuals. Hence, PSM is used for approximating a randomized experiment and reducing the selection bias in observation studies. On average, individuals with same propensity score are balanced on covariates, and the counterfactual (the result for the treated observations if they were instead not treated) can be estimated within that group. The propensity score is the conditional (predicted) probability of receiving treatment given the relevant controls X (Rosenbaum and Rubin, 1983). It can be expressed as:

$$P(X) = \Pr\left[D = \frac{1}{X}\right] = E\left[\frac{D}{X}\right] \text{ -------------- (1)}$$

Where D = [0,1] is the indicator of exposure to treatment and X is the multi-dimensional vector of pre-intervention characteristic. D=1 for treated observations and D=0 for control observations. The propensity scores are estimated using the probit or logit models with dependent variable coded as 1 for BARI maize sheller adopters and 0 for non-adopters of BARI maize sheller. The propensity score is a single index variable that summarizes pre-treatment characteristics of each subject, which makes matching possible. After the propensity score is estimated, the average treatment effect on the treated (ATT) can then be estimated as follows:

$$ATT = E\{Y_1 i^{\uparrow}1 - Y_1 i^{\uparrow}0 \mid D = 1\},$$

$$ATT = E\left[E\{Y_i^1 - Y_i^0 \mid D_i = 1, \rho(X)\}\right]$$

$$ATT = E\left[E\{Y_i^1 \mid D_i = 1, \rho(X)\}\right] - E\{Y_i^0 \mid D_i = 0, \quad \rho(X)\} \mid D{=}1] \text{ .... (2)}$$

Y_i^1 and Y_i^0 are the potential outcomes in the two counterfactual situations of (respectively) treatment and no treatment. Once the propensity scores are estimated, each adopter is matched to a non-adopter with similar propensity score values, in order to estimate the average treatment effect for the treated (ATT). In computing the propensity score matching, in this study, age, education, experience, farm size, family size, training and extension contact were used as independent variables. BARI maize sheller adoption was considered as a dependent variable.

Constraint facing index (CFI)

An overall constraint score in BARI maize sheller in maize farming was computed for each farmer by adding their constraint scores in all 6 constraint items that the farmer identified. The possible range of constraints facing score for each constraint could be 0 to 3 and possible range of overall constraints facing for score for 6 constraints could range from 0 to 18. A constraint facing index (CIF) for each 6 selected constraints was computed by using the following formula (equation 3):

CFI = (Ch × 3) + (Cm × 2) + (Cl × 1) + (Cn X 0) .... (3)

Where,

Ch= Number of responses indicating high constraint;

Cm= Number of responses indicating medium constraint;

Cl = Number of responses indicating low constraint; and

Cn= Number of responses indicating no constraint.

CFI for any of the selected constraint could range from 0 to 123 for BARI maize sheller in maize farming where, 0 indicated no constraint facing and 123 indicated highest constraint facing in maize farming.

Model Diagnostics with Multicollinearity Test

Before going to apply the model, the data were checked for multicollinearity. The test includes variance inflation factor (VIF) was done for model diagnostics. Finally, the test supported that there is no major problem of multicollinearity of the data.

Results and Discussion

Financial profitability and economic impact of maize cultivation using BARI maize sheller

It is essential to the development and management of a farmer to know the production costs and their evolution, sharing the main items on which cost reduction is worth effort. Production cost data also help the farmers in decision making and in adjusting to changes and give the price level under which the product cannot be sold without losses. The returns of the farms also indicate the direction of farm investment and identified the level of profit that the farms captured which also ensured the decision for further investment. Due to adoption of BARI maize sheller, economic benefits of cultivation of maize can be viewed in two ways. First, there is a significant amount of total cost being saved under the adoption of BARI maize sheller as compared to non-adopter. The total cost of production is much higher in the case of non-adopter compared to adopter of BARI maize sheller in maize farming (Table 2).

Farmers save about Tk. 12,024 per ha in terms of the reduced input cost (11.76 % lower than the cost of producing maize by non-users) of adopters of BARI maize sheller. The result is consistent with Aryal et al. (2014) where about Tk. 6,701 per ha can be saved by shifting from conventional tillage (CT) to zero tillage (ZT) based wheat production. The significant difference in input cost of adopter and non-adopters is found in cost of using the higher amount of threshing, seed, labour, and land preparation. For an individual farmer, this gain by adopting BARI maize sheller is quite small. However, this adoption is of additional relevance for farmers, where labor has increasingly become one of the major constraints in agriculture mainly due to the young generation being less attracted by the sector and expanding non-agricultural job markets. The cost of seed is higher in non-adopters compared to adopter, this is largely contribute to total input cost. For non-adopter total cost of threshing is about Tk 15,576 per ha against Tk. 5,424 per ha under adopter. Operational cost of threshing is low due to high capacity of the machine for producing good quality grains for seeding purpose, whereas manual shelling of maize is a time-consuming and tedious operation.

More than 28% cost was spent for fixed inputs, such as land use and family labour for both adopter and non-adopters of BARI maize sheller. The share of total cost was found to be the highest for inorganic fertilizers (18.24-22.28%) followed by family labour (20.80-21.28%) and hired labour (13.87-14.18%) among the cost items (Table 1).

Table 1. Cost of maize cultivation of BARI maize sheller of adopter and non-adopter

Particular	BARI multi crop seeder adopter/user		P(T<=t) two-tail	Non user/non-adopter	
	Tk/ha	%		Tk/ha	%
A. Variable cost (Tk)	70721	69.14	-	81682	71.46
Hired labor	14509	14.18	0.079	15855	13.87
Land preparation using mechanical power	6469	6.32	0.037	6990	6.11
Threshing	5424	5.30	0.00	15576	13.63
Seed	7685	7.51	0.00	9521	8.33
Inorganic fertilizers	22792	22.28	0.090	20846	18.24
Organic fertilizers	1593	1.56	0.011	875	0.77
Pesticide	925	0.90	0.105	614	0.54
Irrigation	10107	9.88	0.822	10000	8.75
Interest on operating capital[1]	1216	1.19	-	1405	1.23
B. Fixed cost (Tk)	31567	30.86	-	32629	28.54
Land use	9802	9.58	-	8847	7.74
Family labor	21764	21.28	0.077	23782	20.80
C. Total cost (A+B)	102287	100.0	-	114311	100.0

[1]Interest on operating capital was calculated for 6 months for maize. Interest rate of 7% per annum was considered for calculation. Interest on operating capital was calculated based on this formula-
Interest on Operating Capital (IOC) = AI×i×t, Where, AI = (Total investment)/2 , i = Rate of interest
t = Length of crop period in months

The yield of maize using BARI maize sheller is much higher compared to non-adopters of BARI maize sheller. The average yield of maize for adopters was 8.95 t/ha which was significantly higher (3.95%) than the yield of maize for non-adopters of BARI maize sheller (8.64 t/ha) (Table 2). Among many other factors, it might be due to timely harvesting and threshing of maize. Because at that time of harvesting and threshing as there is a scarcity of maize sheller farmers face competition for timely threshing. Non-adopter farmers who thresh maize with hands, pick up the maize at their will.

In case of non-adopter farmers, on the average, using BARI maize sheller rather than conventional production for maize in total production process, farmers can achieve additional net revenue amounted to Tk. 23,327 per ha (i.e., the average net return of adopters was Tk. 46526/ha which was also significantly higher (100%) than non-adopters of BARI maize sheller). This is very close to the results obtained by Erenstein and Laxmi (2008) in the Indo-Gangetic Plains (IGP). This higher net return was due to higher yield and high price of the produce and lower cost of threshing. The rate of return (BCR) over total cost was higher than unity, implying that the productions of maize for both adopters and non-adopters of BARI maize sheller were profitable at farm level. The BCR of adopters (1.45) is significantly higher (20.94%) compared to that of non-adopters of BARI maize sheller. Based on overall benefit-cost ratio, we conclude that BARI maize sheller, on the average, provides 21% more total economic benefits to farmers when compared to traditional method of production (non-user).

Table 2. Profitability of maize cultivation of adopter and non-adopter of BARI maize sheller

Particular	BARI maize sheller user/Adopter *(n=41)*	Non user/Non-adopter *(n=79)*
1. Seed yield (kg/ha)	8954	8643
2. Price (Tk/kg)	16.49	15.73
3. Gross return (Tk/ha)	148814	137511
Main product	147179	135534
By-product	1635	1977
4. Total variable cost (Tk/ha)	70721	81682
5. Total cost (Tk/ha)	102287	114311
6. Gross margin (Tk/ha) (3-4)	78093	55829
7. Net return (Tk/ha) (3-5)	46526	23199
9. Rate of return:		
Over variable cost (3÷4)	2.10	1.68
Over total cost (3÷5)	1.45	1.20

Adoption status of BARI maize sheller at farm level

The adoption of BARI maize sheller has influenced on different economic and socioeconomic aspects of farmers. The socioeconomic aspect influence greatly to use new technology. Thus, farmers' socioeconomic profile discusses first and then factors influencing adoption of BARI maize sheller discuss later on.

Socioeconomic profiles of BARI maize sheller adopters and non-adopters

The socioeconomic conditions of adopters of BARI maize sheller are of much important in planning of development activities because the nature and extent of them are influenced largely by such issues.

The age of farmers are key influences on adoption of new farming practices (Singh et al., 1972). Farmers' age also plays a vital role in the farming activities and management. The age of the BARI maize sheller adopters and non-adopters was examined by classifying the farmers into three groups: Up to 30, 31-60, and above 60 years (Table 3). The highest percentage of the adopters and non-adopter farmers belonged to the age group of 31-60 years. This information imply that majority of the adopters and non-adopter farmers were in middle age and were in a position to put more physical effort for maize production.

Table 3. Distribution of BARI maize sheller adopters and non-adopters according to age group

Age group (year)	BARI maize sheller		Total
	Adopter *(n=41)*	Non-adopter *(n=79)*	n = 120
Up to 30	4 (9.8)	22 (27.85)	26 (21.67)
31-60	28 (68.3)	40 (50.63)	68 (56.67)
Above 60	9 (22.0)	17 (21.52)	26 (21.67)
Total	41 (100)	79 (100)	120 (100)

n: sample size; figures in the parentheses indicate percentage

Veerina et al. (1999) stated that factors such as literacy have a role in influencing yields through production decisions. Education is likely to influence the farmers to adopt the modern technology and it makes them more capable to manage scarce resources efficiently so that they can earn higher profit. On the basis of education level, the literacy status of the respondent farmers has been grouped into five categories. The categories are (1) illiterate, (2) primary, (3) secondary, (4) higher secondary and (5) degree and above.

It is observed that the average education level of adopter and non-adopter of BARI maize sheller was 5.12 and 4.28 years of schooling respectively which indicate that adopter farmers have at least primary level of education which is more important in the case of maize farming. Table 4 also showed that 12.20% of adopter farmers of BARI maize sheller and 18.99% of non-adopter farmers respectively did not have formal education. Of the educated respondents, 48.78% and 49.37% adopter and non-adopter respectively had primary level of education and 36.59% and 27.85%

adopter and non-adopter respectively had secondary level of education. A few numbers of adopter (2.44%) and non-adopter (2.53%) of BARI maize sheller had higher secondary level of education respectively (Table 4).

Table 4. Distribution of BARI maize sheller adopters and non-adopters by literacy levels

Literacy level	BARI maize sheller		Total
	Adopter *(n=41)*	Non-adopter *(n=79)*	n = 120
Illiterate (0)	5 (12.20)	15 (18.99)	20 (16.67)
Primary (1-5)	20 (48.78)	39 (49.37)	59 (49.17)
Secondary (6-10)	15 (36.59)	22 (27.85)	37 (30.83)
Higher secondary (11-12)	1 (2.44)	2 (2.53)	3 (2.50)
Degree & above (13 & above)	-	1 (1.27)	1 (0.83)
Total	41 (100)	79 (100)	120 (100)

n: sample size; figures in the parentheses indicate percentage, '-' indicates nil.

At the initial stage of adopting BARI maize sheller, the respondent adopters in the study areas were influenced by different persons at different levels. The influencing persons were reported to be family member and neighboring farmer, CIMMYT, Sub-Assistant Agricultural Officer (SAAO), Agriculture Officer (AO), and the scientist of BARI. Table 5 depicted that neighbor influenced to a greater extent in adopting BARI maize sheller than the influences of other persons. Again, after neighbor major influences came from family members, CIMMYT and SAAO in maize cultivation.

Table 5. Level of influence by different persons in adopting BARI maize sheller

Persons	Level of influence (%)				
	Very high	High	Medium	Low	No influence
Family member	-	17 (41.46)	7 (17.07)	3 (7.32)	14 (34.15)
Neighbor	24 (58.54)	3 (7.32)	14 (34.15)	-	-
DAE personnel	-	9 (21.95)	6 (14.63)	5 (12.20)	21 (51.22)
Scientist of BARI	-	-	6 (14.63)	9 (21.95)	26 (63.41)
CIMMYT	12 (29.27)	4 (9.76)	9 (21.95)	5 (12.20)	11 (26.83)

Figures in the parentheses indicate percentage, '-' indicates nil.

Adoption rate of BARI maize sheller at household level

Around twenty seven percentage (26.73%) of the respondent farmers in Mymensingh district was found to be very much enthusiastic towards BARI maize sheller due to their perceptions of low cost of threshing, less post-harvest loss, device is easy to operate, if there is a storm, it is convenient to thresh early because of it ensures timely threshing and reduce turnaround time, more income from selling high quality maize.

The average land holding size was 0.74 ha and non-adopting households had larger landholdings (0.75 ha) than the adopters (0.73 ha). Average land allocated to maize (0.136 ha) accounted for 18.38% of the total land, with adopting households allocating significant more area to maize (0.14 ha) compared to non-adopters (0.13 ha). After adoption of BARI maize sheller, adopting households allocated significant more area to maize (0.14 ha) compared to before adoption (0.12 ha) of it. Maize area increased by 14.30% as a result of adoption of BARI maize sheller (Fig. 1).

Factors influencing adoption of BARI maize sheller

Factors influencing adoption of BARI maize sheller was examined by using probit regression. The results of the Probit Model (Table 8) revealed that three factors were significant in influencing farmers' decision to adopt BARI maize sheller in maize cultivation. From Table 6, increase in experience relatively favoured the decision to adopt BARI maize sheller in the study area by 1.44%. Adoption of BARI maize sheller was positively associated with the level of education of a farmer. Adoption of BARI maize sheller on the other hand was negatively correlated with household size by 1.54.

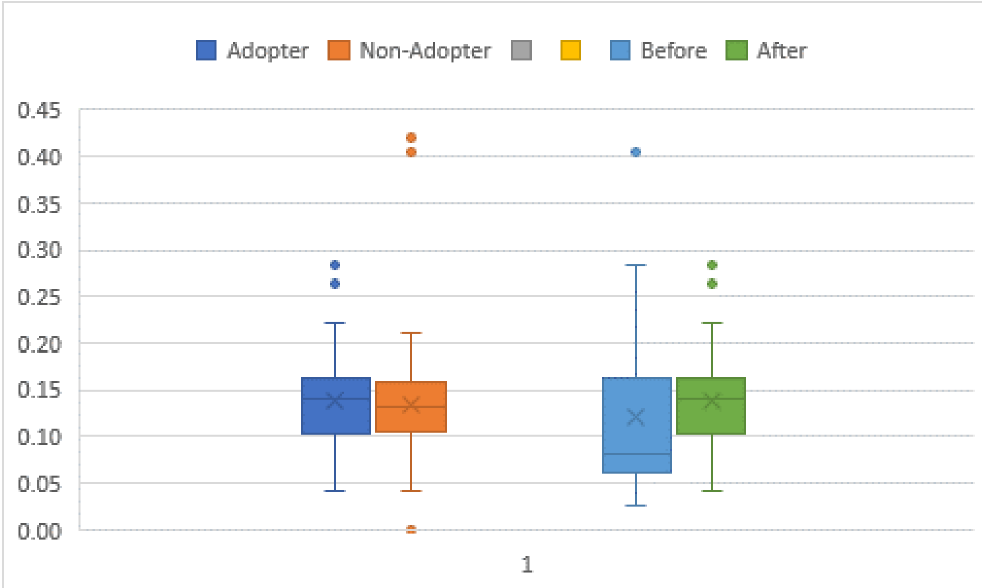

Figure 1. Maize area of adopters and non-adopters and area of adopters before and after adoption of BARI maize sheller

Table 6. Results of the probit regression for BARI maize sheller adoption in study area

Variables/PC	Coefficients	Std. Error	z value	Pr(>|z|)
Age (year)	-0.00524	0.0103	-0.51	0.609
Education (Year of schooling)	0.06394*	0.0400	1.60	0.100
Maize farming experience (Year)	0.11445***	0.0317	3.61	0.000
Farm size (Decimal)	0.00048	0.0012	0.42	0.677
Family size (Number)	-0.15413**	0.0661	-2.33	0.020
Training on maize cultivation Dummy (Yes=1; No = 0)	0.21749	0.2612	0.83	0.405
Intercept	-0.8801	0.6082	-1.45	0.148
Sample size		120		
Pseudo R^2		0.1586		

*,**, and*** significant at 10, 5 and 1%, respectively

Estimation of treatment effect-matching algorithms: impact on productivity of maize

The impact of adoption of BARI maize sheller on productivity of maize is presented in Table 7. Adoption of BARI maize sheller significantly affected maize productivity. According to the Nearest Neighbour, causal effect of technology adoption on maize productivity is highly significant and equal to 327.08 , which is the average maize productivity difference between adopters of BARI maize sheller and non-adopters, i.e. adopters were significantly (P<0.01) better than non-adopters by 327 kg in maize productivity in Nearest Neighbour matching method.

Table 7. Impact of BARI maize sheller adoption on productivity of maize

Matching Algorithm	Adopters (N)	Non-adopters (N)	ATT	Std. Err.	T
Nearest Neighbour	40	24	327.08**	425.91	0.768
Kernel-based	40	65	291.09**	394.71	0.737

Using Kernel-based matching method, the effect of BARI maize sheller technology on maize productivity was positive and highly significant (Table 7). The average treatment effect on the treated (ATT) estimates suggest that BARI maize sheller adoption significantly increased the maize productivity by about 291.09 kg per ha. This might be due to along with other maize management practices timely harvesting and threshing of adopter farmers tends to having higher yield. This is the average change in productivity per ha of farm households that contributed by a change in technological status. These results confirm that adoption of BARI maize sheller improved or increased the maize productivity of the adopters. A study by Awotide et al., 2012 in Nigeria using a Local Average Treatment Effect (LATE) found that a positive impact of improved rice varieties on rice productivity and the study of Paudel *et el.* also found that mini-tiller increased rice productivity by 1,110 kg/ha (27%) which is supported by this present study.

Impact on farm household income of maize farmers

The two matching estimates showed that BARI maize sheller adoption had a positive and significant effect on farm household income (Table 8). The nearest neighbour matching algorithm indicated that the effect of adoption of BARI maize sheller was significant (P<0.05) and equal to 0.500. Since income was expressed in logarithmic terms, the average income ratio between adopters and non-adopters was about 1.65 implying that the income of adopters was almost 65% higher than income of non-adopters. Similarly, the estimates of the Kernel-based matching showed that the income of adopters was almost about 34% higher than income of non-adopters. This result suggests that adoption of BARI maize sheller make adopters on average better off by 34 to 65% compared to the non - adopter counterparts in maize cultivation.

Table 8. Impact of BARI maize sheller adoption on income of maize farmers

Matching Algorithm	Adopters (N)	Non-adopters (N)	ATT	Std. Err.	T
Nearest Neighbour	40	24	0.500**	0.229	2.402
Kernel-based	40	65	0.292**	0.290	1.008

Problems and constraints of adopting of BARI maize sheller at farm level

The adopter has identified several problems of BARI maize sheller. Based on the farmers opinion a constraint facing index (CFI) was developed and ranked the problems with their intensity. The computed CFI of the 6 constraints ranged from 9 to 115 for BARI maize sheller. Majority of the farmers mentioned that non-availability of machine in peak period, wastage/broken cobs are the major problems in the study areas and the computed value of CFI was 115, 74 for BARI maize sheller in maize farming. Most of the respondents opined that the non-availability of machine due to lack of capital of the respondents and complicacy of receiving subsidy to purchase machine. For breaking cobs, they opined that the grains break due to less quantity of cobs. Due to lack of training facilities, farmers had many difficulties to operate machine thereby resulting in lower yield. The extent of takes more time to dry the kernels and crops other than maize cannot be threshed were also problems that identified farmers (Table 9).

Table 9. Six selected constraints along with constraints facing index and rank order in maize farming

Name of the constraints	Extent of constraints (N = 41)				CFI	Rank order
	High (3)	Medium (2)	Low (1)	Not at all (0)		
Non-availability of machine in peak period	35	4	2	0	115	1
Wastage/broken cobs	22	3	2	19	74	2
Lack of cash in hand	9	3	2	14	32	3
Lack of training facilities	8	1	1	31	27	4
Takes more time to dry the kernels	3	1	1	36	12	5
Crops other than maize cannot be threshed	2	1	1	37	9	6

Conclusion

The shrinkage of cultivable land and shortage of agricultural labour demanding more farm mechanization in Bangladesh. Agricultural intensification and productivity gain from agriculture can be achieved through adoption of new technology. BARI maize sheller can take the opportunities as an engine of productivity gain of agricultural produces. This study assessed the adoption impacts of BARI maize sheller in maize farming in Bangladesh. The results showed that shifting from conventional production to partial mechanized production system in maize farming reduces the farmers total input cost per ha by 11.76% and increases net revenue per ha by 100% respectively. The levels of adoptions of BARI maize sheller was 26.73%. Different socioeconomic factors namely experience of the farmer and education have significantly influenced farmers to adopt BARI maize sheller and family size negatively have influenced farmers to adopt BARI maize sheller. The study also showed that BARI maize sheller adoption on average increased maize productivity of adopters by about

327.08 kg per ha than the non-adopters. BARI maize sheller makes adopters on average better off by 34 to 65% compared to the non-adopter counterparts in maize cultivation. The results provide evidence for heterogeneous effects of adoption of BARI maize sheller on farm income and productivity of maize. Hence, the adoption of improved technologies had a positive effect on maize productivity and farm household income, thereby increasing their likelihood of decreasing poverty levels. The results also provide evidence that agricultural technology adoption can contribute to improving productivity and raising income of farm households. Majority of the farmers mentioned that non-availability of machine in peak period, broken cobs and lack of cash in hand are the major problems in the study area and the computed value of CFI was 115, 74 and 32 for BARI maize sheller in maize farming respectively. Productivity and income enhancement call for a concerted effort to alleviate the key constraints and to enable the further uptake and scaling of the promising BARI maize sheller among farming communities.

Availability of machine at farm level is one of the pre-requisites of the adoption of improved technologies. So, BARI maize sheller should be made locally available to the service providers/farmers. In order to make the machine available to the service providers/farmers, existing pilot programme, and block farming of improved technologies should be strengthened and extended to the presence of BARI maize sheller technology intervention areas. Besides, Government should encourage private companies and DAE to produce sufficient quantities of the machine and supply this machine to interested service providers/farmers at reasonable price. BARI in collaboration with DAE should be taken demonstration programme and continued until adequate awareness is created among the farmers/service providers to make this machine available. Awareness program is an important tool that enhances up-to-date knowledge and skill of the service providers/farmers. Regular awareness and training program on operation of BARI maize sheller and other related technologies should be organized for service providers/farmers, extension workers, and private companies for more efficient operation, the efficient use of inputs and production technologies. Also, programs on repair and maintenance of BARI maize sheller for operators is highly required so that they will be more aware of the benefits of improved technologies. A key policy implication of these differential impacts is that the positive impacts of BARI maize sheller on farmers' productivity and income could be reinforced if, for instance, technology intervention and schools expand.

Authors Contribution

Mst. Esmat Ara Begum: Conceptualization, Data curation, Formal analysis, Writing - original draft, Writing - review & editing, Md. Kamrul Hasan: Conceptualization and review & logistics Morsalina Khatun: Conceptualization and review and Mohammad Ismail Hossain: Conceptualization, Writing - review & editing.

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Competing interests

The authors have declared that no competing interests exist.

References

Alam M. M. and M. A. Momin, 2009. Performance of existing maize shellers in Bangladesh. *Progressive Agriculture,* 20(1 & 2): 207– 220.

Aryal, J.P., Sapkota, T., Jat, M., Bishnoi D.K. 2014. On-farm economic and environmental impact of zero-tillage wheat: a case of north-west India. *Experimental Agriculture,* 51(1): 1-16*.* https://doi.org/10.1017/S001447971400012X

Awotide, B., Diagne, A. and Omonona, B. 2012. Impact of improved agricultural technology adoption on sustainable rice productivity and rural farmers' welfare in Nigeria: A Local Average Treatment Effect (Late) Technique. *African Economic Conference.* Kigali, Rwanda. http://www.afdb.org/fileadmin/uploads/afdb/Documents/Knowledge/Impact%20of%20Improved%20Agricultural%20Technology%20Adoption%20on%20Sustainable%20Rice%20Productivity%20and%20Rural%20farmers%27%20Welfare%20in%20Nigeria%20A%20Local%20Average%20Treatment%20Effect%20%28LATE%29%20Technique_02.pdf. Accessed 16/01/2022.

BBS. 2019. *Statistical Yearbook of Bangladesh*, Ministry of Planning, Government of the Peoples' Republic of Bangladesh, Dhaka, Bangladesh.

Buliaminu, K. 2011. Development of a roll-in oriented machine for maize shelling. *Journal of Materials Science and Engineering*, B1: 530-535. DOI:10.17265/2161-6221/2011.09.018

Erenstein, O. and Laxmi, V. 2008. Zero tillage impacts in India's rice–wheat systems: a review. *Soil and Tillage Research,* 100:1–14. https://doi.org/10.1016/j.still.2008.05.001

Faisal, I.M. and Parveen, S. 2004. Food Security in the Face of Climate Change, Population Growth, and Resource Constraints: Implications for Bangladesh *Environmental Management,* 34(4):487-98. https://doi.org/10.1007/s00267-003-3066-7

FAO (Food and Agriculture Organization of the United Nations), 2008. Agricultural Mechanization in Africa, Time for Action. Planning Investment for Enhanced Agricultural Productivity Report of an Expert Group Meeting. Vienna and Rome, Food and Agriculture Organization of the United Nations and (UNFAO) United Nations Industrial Development Organization (UNIDO). http://www.fao.org/docrep/017/k2584e/k2584e.pdf (accessed 14.05.15.).

Godfray, H.C.J. and Garnett, T. 2014. Food security and sustainable intensification. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 369 (1639): 1-10. https://doi.org/10.1098/rstb.2012.0273

Kabir, M.S. Salam, M.U., Chowdhury, A., Rahman, N.M.F., Ifterkharuddaula, K.M., Rahman, S., Rashid, M.H., Dipti, S.S., Islam, A., Latif, M.A., Islam, A.K.M.S., Hossain, M.M., Nessa, B. Ansari, T.H., Ali, M.A. and Biswas, J.K. 2015. Rice Vision for Bangladesh: 2050 and Beyond. *Bangladesh Rice Journal*, 19(2): 1-18.

Paudel G.P.D., Bahadur K.C., and McDonald, A.J. 2019. Scale-appropriate mechanization impacts on productivity among smallholders: Evidence from rice systems in the mid-hills of Nepal Land Use. *Policy,* 85: 104–113.

Kienzle, J., Ashburner, J.E. and Sims, B.G., 2013. Mechanization for Rural Development: A Review of Patterns and Progress from Around the World. Plant Production and Protection Division, Food and Agriculture Organization of the United Nations (FAO), Rome.

Milufarzana, Rahman, A., Alam, M.M. and Ahmed, M.R. 2015. Economic parameter of maize sheller for custom hire service in Bangladesh, *AgricEngInt: CIGR Journal,* 17(2): 146-150.

M. M. Alam and M. A. Momin, 2009. Performance of existing maize shellers in Bangladesh. *Progressive Agriculture* 20(1 & 2): 207 – 220. https://doi.org/10.3329/pa.v20i1-2.16873

Rosenbaum, P.R. and Rubin, D.B. 1983. Assessing sensitivity to an unobserved binary covariate in an observational study with binary outcome. *Journal of the Royal Statistical Society Series B.* 45:212–218.

Singh, L.R., Bhah J.P. and Jain S.L., 1972. Socio-economic factors and the adoptions of improved farm practices. *Man in India,* 52(4): 320-327.

Tilman, D., Balzer, C., Hill, J., Befort and B.L., 2011. Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Science of the United States of America,* 108 (50): 20260-20264. https://doi.org/10.1073/pnas.1116437108

Veerina, S.S., Nandeesha, M.C., De Silva, S.S. and Ahmed, M., 1999. An analysis of production factors in carp farming in Andhra Pradesh, India. *Aquaculture Research,* 30(11-12): 805-814. https://doi.org/10.1046/j.1365-2109.1999.00397.x

Zhang, X., Rashid, S., Ahmad, K. and Ahmed, A., 2014. Escalation of real wages in Bangladesh: is it the beginning of structural transformation? *World Development,* 64: 273-285. http://www.sciencedirect.com/science/article/pii/S0305750X14001740. Accessed 16/01/2022.