ADOPTION IMPACTS OF CONSERVATION AGRICULTURE TECHNOLOGY AT FARM LEVEL IN BANGLADESH

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Abbreviations

BARI = Bangladesh Agricultural Research Institute
BRRI = Bangladesh Rice Research Institute
CA = Conservation Agriculture
DAE = Department of Agriculture Extension
FGD = Focus Group Discussion
FYM = Farm Yard Manure
ICM = Integrated Crop Management
IPM = Integrated Pest Management
LSP = Local Service Provider
NGO = Non-Government Organization
OLS = Ordinary Least Square
PSM = Propensity Score Matching
PTOS = Power Tiller Operated Seeder
RCT = Resource Conservation Technology
SAAO = Sub-Assistant Agriculture Officer
VMP = Versatile Multi-crops Planter
2-WT = Two Wheel Tractor

Conversion rate: 1 $ = 81.00 BDT (as on August 05, 2017)

Adoption Impacts of Conservation Agriculture Technology at Farm Level in Bangladesh

M. A. Monayem Miah[1], M. A. Rashid[2], M. Enamul Haque[3] and Richard W. Bell[4]

Abstract

The study was conducted at three *Upazilas* of Rajshahi and Thakurgaon districts, Bangladesh to assess the adoption status and impacts of conservation agriculture (CA) technologies at farm level during January-February, 2017. A total of 405 farmers taking 135 CA technology adopters and 270 non-adopters were selected randomly for this study. The study revealed that CA technology adoption is still going on in the study areas. However, the rates of adoptions of crop residue retention (67%) and crop rotations (38.9%) within two years were much higher compared to minimum tillage (18.6%). The rate of residue retention (68.9%) and suitable crop rotations (34.4%) adoption was also found high in non-adopters areas. The age, innovativeness, and extension contact of the farmers and availability of VMP had significant positive influence on the adoption of CA technologies. CA technology could save human labour up to 34.1%, seed 31.4%, fertilizers 6.14%, pesticides 32.4% and total cost of production up to 9.80% in cultivating lentil, mustard, maize, and wheat. Again, it increased crop yield and net profit up to 28.2% and 460% respectively. Propensity score matching (PSM) methods further confirmed that CA technology adoption had significant impacts on increasing crop yield, reducing variable costs, and increasing adopters' net income. However, the major problems of higher technology adoption in the study areas were non-availability of minimum tillage planter, lack of knowledge and awareness of the farmer, and no/little subsidy provision on planter. Availability of minimum tillage planter, provide training to local service providers on CA methods, and subsidy provision on CA machineries may be the solutions of the aforesaid problems.

Key words: Conservation agriculture, conservation tillage, conventional tillage, VMP, residue retention, crop rotations, and propensity score matching

1. INTRODUCTION

Agriculture in Bangladesh is well advanced in the adoption of farm mechanization particularly in land preparation (tillage/paddling/laddering) by imported 2-wheel tractors, irrigation, and threshing. However, the growing threat to crop production is the shortage of labour which impacts especially on crop establishment; harvesting and weed control (Islam et al., 2013). In addition, prices of inputs such as labour, seed, fertilizer, pesticides, diesel, and irrigation water are also increasing that affects their optimum use, crop productivity and farm profitability (Reza et al., 2016). Thus, Bangladesh agriculture is facing the challenge of increasing food security for its growing population and improving overall land use sustainability, while decreasing the need for labour, the costs of crop production and increasing farm profitability. Therefore, more foods have to produce from decreasing cultivable land through more efficient use of land and crop management technologies and through using natural resources that have minimal adverse impacts on soil and environment

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(Fischer et al., 2009). In this context, conservation agriculture (CA) and mechanization are becoming increasingly important to overcome the problems of declining agricultural productivity in Bangladesh. Conservation agriculture offers a powerful option for meeting future food demands and contributing to sustainability of agriculture and rural development (Hobbs et al., 2008). It has the capacity to make more water available to the crops, and can mitigate, to some extent, the present climatic and socio-economic challenges faced by farmers (Alam et al., 2016b).

Conservation agriculture is not an actual technology; rather, it refers to a wide array of specific technologies that are based on applying one or more of the three main CA principles (IIRR and ACT, 2005). The principles are (a) reducing the intensity of soil tillage (minimal soil disturbance); (b) covering the soil surface adequately (crop residue retention); and (c) diversifying crop rotations (Hobbs et al., 2008). Therefore, the productivity increase and sustainability of CA systems largely depend on tillage operations, systematic crop rotations, and *in situ* crop harvest residue management coupled with adequate crop nutrition. Conservation agriculture is a win-win approach that reduces operational costs, including machinery, labour, and fuel, while increasing yields and better utilizing natural resources (Roy et al., 2009). Soil tillage is one of the most important activities of agricultural land management which has significant impact on soil physical, chemical, and biological properties that affect crop yield (Keshavarzpour and Rashidi, 2008). Minimum tillage practice increases the levels of soil organic matter (Busari and Salako, 2013; Mina et al., 2008), water retention capacity (Aziz et al., 2013; Lal, 2013), irrigation requirements (Derpsch et al., 2010; Johansen et al., 2012) and decreases production costs. Islam et al. (2010) found that 41-43% less irrigation water was used by crops established by VMP planting as compared to a traditional tillage system. Sarker et al. (2012) concluded after reviewing extensive literature that the field performances of minimum tillage implements were much better than conventional ones. They also stated that CA practices on 2WT in Bangladesh could successfully save considerable amount of crop establishment cost and increase yields. Two-wheel power tiller operated CA based crop establishment technologies could improve input utilization and soil health, while underpinning sustainable crop production and crops diversification (Hossain et al., 2014). Farmers of triple crops cropping systems in Bangladesh accept CA based technologies considering the advantages of higher yields, reduced cost of production, and minimized turn-around time between the crops (Hossain et al., 2015**).** However, the development of a range of minimum soil disturbing planters for 2WT over the past decade and nation-wide spread of mechanized tillage with two-wheel tractors (2WT) provide a platform for implementing CA principles which decrease the costs of crop production (Haque et al., 2014) and improve the fertility of soils in Bangladesh.

Crop residue retention on the top of the soil with any number of tillage systems plays a crucial role in improving agronomic productivity and environmental quality (Alam et al., 2016a; Salahin et al., 2017). It significantly modifies various agronomic factors by increasing and stabilizing the soil moisture content, altering fertility and temperature in the topsoil layer, reducing soil erosion, nematode and sunlight incidence on the soil surface (Silva et al., 2003; Velini and Negrisoli, 2000; Vidal and Theisen, 1999; Amado et al., 1989). Straw coverage under no-tillage system increases organic matter, total nitrogen and phosphorus in the soil compared to conventional tillage with no coverage (Wang et al., 2008). Long-term crop residue incorporation builds SOM level and N reserves, and increases the availability of macro- and micro-nutrients (Singh et al., 2005). Again, the retention of crop residues can substantially reduce the amount of inorganic fertilizers use which brings both environmental and economic benefits to the farmers (Tiwari, 2007). Knowingly or unknowingly the benefits of residue retention, many farmers are retaining crop residues in their crop fields over the years which also provide a platform of implementing CA principles throughout the country.

A crop rotation is the practice of growing a series of different types of crops in the same area over a sequence of seasons (https://en.wikipedia.org/wiki/Crop_rotation). Continuously growing the same crop will tend to exploit the same soil root zone which can lead to a decrease in available nutrients for plant growth and to a decrease in root development (Kumar, 2004). It has many agronomic, economic and environmental benefits over continuous cropping. Therefore, another important way to improve SOM is suitable crop rotations that have also enormous effects on soil physical and chemical properties and thereby on crop productivity (Ranamukhaarachchi et al., 2005; Alam et al., 2016a). Crop rotation can help maximize crop yield potential and profitability over time (Lauer, 2010), control weeds (Cavigelli, 2013; Jacobsen et al., 2012), break disease cycles, limit insect and other pest infestations (Teetes and Pendelon, 1999), increase soil organic matter, and provide an alternative source of nitrogen (Mallarino and Enrique, 2006; Khan et al., 2007; Murell, 2011). Besides grain crops, the inclusion of legume in a cropping pattern can maintain soil fertility and sustain crop productivity to a great extent.

CA based tillage technology was first introduced at farm level in Bangladesh by CIMMYT for wheat cultivation in late 90's with minimum till technology by 2WT operated seeder. The 2WT operated CA based planting technology were developed by different research organizations and promotional activities are being conducted at farm level for yield gap minimization, water saving, efficient input use, soil health improvement, sustainable crop production, and crop diversification (Hossain et al., 2015). The scientists of Murdoch University, West Australia with the support of Australian Government and in collaboration with Bangladesh Agricultural University, Bangladesh Agricultural Research Council, BARI, BRRI, Department of Agricultural Extension, Department of Agriculture and Food of Western Australia, and NGOs has implemented the project "Overcoming Agronomic and Mechanization Constraints to Development and Adoption of Conservation Agriculture in Diversified Rice-based Cropping in Bangladesh" funded by Australian Centre for International Agricultural Research (ACIAR) since April 2012 to March 2017. The aim of the project was to develop and accelerate the adoption of CA for selected soils, crops and cropping systems in Bangladesh, especially in rainfed areas and those with supplementary irrigation, so that farmers and households can get benefit from cost saving crop production technologies and sustainable resource management. Different crops such as wheat, maize, pulses, oilseeds, jute, and rice can be established and grown successfully through CA technology (Barma et al., 2014; Alamgir et al., 2015). At the end of this project, an attempt was made to evaluate the impacts of CA technology adoption at farm level for providing feedback of the project to researchers and policy makers who can formulate appropriate policy guidelines to extend the project activities in other new areas of the country.

Objectives

1. To determine the status of adoption and factors influencing CA technology adoption at farm level.
2. To estimate the impacts of using CA technologies on input use, crop productivity and farm profitability.
3. To determine the problems and constraints of adopting CA technologies at farm level.
4. To recommend some policy guidelines for expanding CA technologies to other parts of the country.

2. METHODOLOGY

2.1 Study Area Selection

CA technologies have been implemented or are being practiced in seven Upazilas in four districts of Bangladesh namely Rajbari, Thakurgoan, Rajshahi and Mymensingh. Considering project resources, logistic support and CA adoption, three Upazilas namely Durgapur and Godagari Upazilas of Rajshahi district and Sadar Upazila of Thakurgoan district were purposively selected for the study.

2.2 Sampling Design

The households were selected considering the level of adoption of CA technologies. At first, a complete list of CA technologies adopted farmers[2] was prepared with the help of personnel from DAE and CA project. Then, a total of 135 CA technology adopted farmers taking 45 farmers from each Upazila were selected randomly for this study. Again, a total of 270 non-adopting farmers were randomly selected for this study as control. Thus, the total sample size was 405.

Finally, a total of 5 Focus Group Discussion (FGD) were conducted in the study areas in order to supplement primary data and information. A focused group was formed with different sections of people such as Agriculture Officer (1), Sub-Assistant Agricultural Officer (2), 2-WT owner (1), VMP owner & service providers (2), VMP users (2), 2-WT users (2), local machinery supplier/dealer/seller (1), VMP mechanic (1), and agricultural inputs dealer (1).

2.3 Data Collection Technique

Both qualitative and quantitative techniques of data collection were adopted in the study. Quantitative data and information were gathered from selected farmers using a pre-tested interview schedule. Qualitative techniques were based on FGD. Data were collected during the period from January to February, 2017.

2.4 Analytical Techniques

After completion of field survey, collected data were edited, scrutinized, summarized and analyzed using computer software. Descriptive statistics were mostly used to present the results of the study. Moreover, the following analyses were also done to fulfill the objectives of the study.

2.4.1 Determinants of CA technology adoption

Many authors in the past used Logit and Probit regression model to find out the factors influencing modern agricultural technologies adoption or to examine the role of an intervention to development. Malik et al., (1991) used Probit model to examine the role of credit in agricultural development. Heisey et al. (1990) used Logit model to identify the determinants of farmers' awareness and adoption of wheat varieties. Again, Alam et al. (2010) estimated the factors of food security using Logit model. However, both approaches produce similar results when estimating the probability of an individual farmer being an adopter or a non-adopter (Caliendo et al., 2005). In this paper, the Probit model was chosen to find out the factors influencing CA technologies adoption.

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[2]The farmers who adopted three CA principles such as crop cultivation with minimum soil disturbance, retention of crop residues in the field, and practice suitable crop rotations are treated as CA farmers. Minimum two years experienced CA farmers were selected as sample CA farmers for this study.

In order to ascertain the probability of adoption of CA technologies, the following Probit model was used. Since the dependent variable is dichotomous, OLS cannot be used. MLE method was followed to run the Probit model using STATA software (Version 12). The specification of the model was as follows:

$$\text{Probit}\{P(Y=1)\} = \log\{P/(1-P)\} = \alpha + \beta_1X_1 + \beta_2X_2 + \ldots\ldots + \beta_KX_K$$

Where, Y is a categorical response variable with 1= adopters and 0 = otherwise; α is the intercept; β_1, β_2.... β_k are coefficients of independent variables X_1 X_2... X_K; P is the probability of adopting CA technology, and (1-P) is the probability that a farmer does not adopt CA technology.

The empirical Probit model was as follows:

$$Y = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8$$

Where, Y= Dependent variable (1= Adopter, 0 = Non-adopter), X_1 = Farmer's age (year), X_2 = Education (year of schooling), X_3 = Family size (No./HH), X_4 = LnFarm size (decimal), X_5 = Availability of VMP (score), X_6 = Societal membership (wt. score), X_7 = Innovativeness (wt. score), X_8 = Extension contact (wt. score), α = Constant,
β_1 β_2 β_3 β_4 .... β_8 are the coefficients to be estimated.

2.4.2 Assessment of impacts of CA technology adoption

The evaluation of CA technology adoption was measured *'With'* and *'Without'* its adoption. Costs and returns were measured at their exchange value, at the time to accrual. It is very important to collect and analyze the current information on input use, output produced and their prices. This represents the key components in the evaluation of conservation measures. However, detailed costs paid for items such as equipment and power, seeds and fertilizers, pesticides and herbicides, labour, and irrigation were collected from the respondents. The cost resources were estimated by systematic listing of physical resources used in the production and it provided the value of each resource on hectare basis. T-test was also employed to show the level of significant difference between the costs and returns of crops cultivated under CA and conventional methods.

2.4.3 Propensity score matching for overall impact evaluation

In order to overcome selection bias, different propensity score matching (PSM) methods were used to estimate the overall impact of CA technology adoption on crop yield, variable cost and farm profitability. Propensity score is the conditional probability of assignment to a treatment given a vector of covariates including the values of all treatment confounders (Rosenbaum and Rubin, 1983). In other words, a propensity score is the probability of receiving treatment given a vector of observed variables, i.e., $p(x) = Pr(\text{l} = 1|\text{X} = x)$.

In the case of impact evaluation of any intervention, it is not possible to observe individual treatment effects, as we do not know what the outcomes for untreated observations would be under treatment and what they would be for the treated when not under treatment; this is known as a *counterfactual*. PSM methods help in creating a counterfactual from the control group. According to Heckman et al., (1998), the basic assumption of using a counterfactual is that the untreated samples approximate the treated samples if they had not been treated, i.e., $E((Y_{0i}|\text{I} = 1)$. The conditional independence assumption (CIA) must hold true for validating a matching method. The CIA argues that project outcomes are independent of project participation conditional on a set of observables (X), which can be written as:

$$(Y_1Y_0) \perp I|\text{X} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

This assumption implies that the selection is exclusively based on observable characteristics, and all of the variables that influence assignment and potential outcomes simultaneously are observed by the researcher. This assumption also implies that the counterfactual outcome for the treated group (CA technology adopter) is the same as the observed outcomes for the non-treated group (non-adopters) given by the control variables (X). In the present study, the counterfactual crop yield, variable cost, and farm net income are the same as the crop yield, variable cost, and farm net income that would have existed if the farmers had no access to the CA technology adoption, which is specified as:

$$E(Y_0|\mathrm{X}, \mathrm{I}=1) = E(Y_0|\mathrm{X}, \mathrm{I}=0) = E(Y_0|\mathrm{X}) \quad (2)$$

The above equation (2) represents the counterfactual crop yield or variable cost or farm net income of the treated group and is equal to the observed crop yield or variable cost or farm net income of the control group. Therefore, under conditional independence, the average treatment on treated (ATT) for crop yield or variable cost or farm net income can be computed as:

$$ATT = E(Y_1 - Y_0|\mathrm{X}, \mathrm{I}=1) = E(Y_1|\mathrm{X}, \mathrm{I}=1) - E(Y_0|\mathrm{X}, \mathrm{I}=1) \quad (3)$$

Balancing properties need to be satisfied for validating propensity score ('pscore'). It implies that two farmers with the same probability of adopting CA technology will be placed in the treated and control samples in equal proportions. The idea behind balancing tests is to test whether the 'pscore' is an adequate balancing score, that is, to test to see if at each value of the 'pscore', X has the same distribution for the treatment and control group (Lee, 2006). The 'pscore' is estimated by a binary choice model. In this paper 'pscore' was estimated by a probit model. Once the 'pscore' is estimated, the data are split into equally spaced 'pscore' intervals, implying that, within each of these intervals, the mean 'pscore' of each conditioning variable is equal for the treated and control farmers, known as balancing property. A further requirement for 'pscore' is the common support which implies that persons with same X values have a positive probability of being both a participant and non-participant (Hecman et al., 1999). Common support can be written as:

$$\text{(Overlap)} \qquad 0 < P(I = 1|\mathrm{X}) < 1 \quad (4)$$

There are different methods to estimate ATT. Nearest Neighbour (NN), Kernel, and Radius matching methods were used in this study. Although each method has its own limitations and strengths, the use of different methods has an advantage of testing the robustness of impact estimates (Becker and Ichino, 2002). A brief discussion of these three PSM methods is given below.

Nearest neighbour matching method: Nearest neighbour is the most straightforward matching estimator. The Nearest neighbour matching (NNM) matches each farmer in the adopter group with farmers in the non-adopter group, based on the closeness of their propensity scores. In NNM, it is possible that the same farmer in the control group can neighbour more than one farmer in the treated group. Therefore, after matching, the difference between their crop yield/variable cost/net income is calculated as the average effect of CA technology adoption on farmer's crop yield/variable cost/net income (ATT). A NNM set can be written as:

$$C(i) = min_j \parallel Pi - Pj \parallel \quad (5)$$

Where $C(i)$ is the set of control units matched to the treated unit *i* with an estimated value of the propensity score of Pi. Let, T be the set of treated and *C* the set of control units and Y_i^T and Y_i^C be the observed outcomes of the treated and control units, respectively. Then, the NNM can be written as:

$$NN^M = \frac{1}{N^T}\sum_{i\in T} Y_i^T - \frac{1}{N^T}\sum_{j=C} w_j Y_j^C \text{ .... (6)}$$

Where, the weights w_j are defined as $w_j = \sum_i w_{ij}$

Kernel matching method: Kernel matching is simply a Kernel density function. Here, all of the observations in the comparison group inside the common support region are used. The counterfactual outcome for adopter i is computed as a kernel-weighted average of the outcomes of all non-adopters. The weight assigned to non-adopter j is in proportion to how close he is to adopter i. Here the neighborhood is:

$$C(pi) = \{j|h > \| Pi - Pj \|\} \text{ .... (7)}$$

Where h is the tolerance level.

The kernel matching method is described by Heckman et al., (1998) as follow:

$$E(\Delta Y) = \frac{1}{N}\sum_{i\in T}[Y_{i,1} - \frac{\sum_{j=1}^{N_i^C} Y_{j,0}^i K(\frac{P(X_{j,0}^i)-P(X_{i,1})}{b_W}}{\sum_{j=1}^{N_i^C} K(\frac{P(X_{j,0}^i)-P(X_{i,1})}{b_W}}] \text{ .... (8)}$$

Where, T is the set of observations that are in the treatment group (adopter), and N is the number of treated cases; $Y_{i,1}$ and $X_{i,1}$ are the dependent and independent variables for the i^{th} treated case; $Y_{j,0}^i$ and $X_{j,0}^i$ are the dependent and independent variables for the j^{th} control case that is within the neighborhood of treatment case i, i.e. for which $|P(X_{j,0}^i) - P(X_{i,1})| < b_w/2$; N_i^c is the number of comparison cases within the neighborhood of i; $K(\cdot)$ is a kernel function; and b_w is a bandwidth parameter. In practice, the choice of $K(\cdot)$ and b_w are somewhat arbitrary.

Radius matching method: This concept came from Caliper matching method. Caliper matching is similar to nearest neighbour matching, but it has an additional restriction. The restriction is that the treated and control propensity scores must be within same caliper (radius) to avoid bad matches. In the caliper method, treated and control units are sorted randomly and the nearest control's propensity score within the caliper is found. Radius methods differ in that in the Caliper method, treated observations are compared with the nearest control's propensity score within same caliper, but the radius matching method not only uses the closest propensity score within each caliper but all the individuals in the control group within the caliper. Radius matching method was first used by Dehejia and Wahba (2002). Radius matching method is estimated as:

$$C(i) = \{P_j : \| Pi - Pj \| < r\} \text{ .... (9)}$$

Where, treated i is matched with all controls' units propensity scores that fall within same caliper r.

Functionally, the radius matching method is as follows:

$$R^M = \frac{1}{N^T}\sum_{i\in T} Y_i^T - \frac{1}{N^T}\sum_{j=C} w_j Y_j^C \text{ .... (10)}$$

Where, the weights w_j are defined as $w_j=\sum_i w_{ij}$

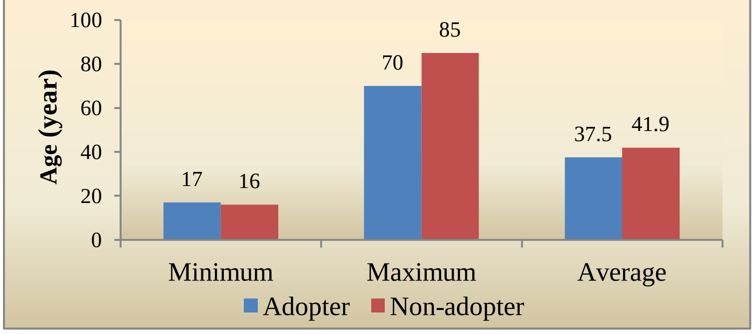
3. RESULTS AND DISCUSSION

3.1 Socioeconomic Profile of the Respondent Farmers

Socio-economic characteristics of the farmers are important in taking farm decision and production planning. There are several interrelated and constituent attributes that characterize a person and these profoundly influence development behavior. Hence, the socioeconomic characteristics of the respondent farmers such as age, education, occupational status, farming experience, land holding, status of societal membership, cosmopolitans, innovation, and extension contact etc. are discussed in the subsequent sections.

Age**:** The age of farmers plays an important role to adopt new technology and in the better management of the farming activities. The age of respondent farmers was examined by classifying minimum, maximum, and average years (Fig 1). The average age of the CA adopters was 37.5 years, whereas it was 41.9 years for non-adopters. The range of their age was from 17 to 70 years for adopters and 16 to 85years for non-adopters in the study areas. This information imply that majority of the farmers were relatively younger and middle aged and were in a position to put more physical effort for farming activities. Farmers belonging to this age group were supposed to have enormous vigor and risk bearing ability.

Fig 1. Age of the respondent farmers

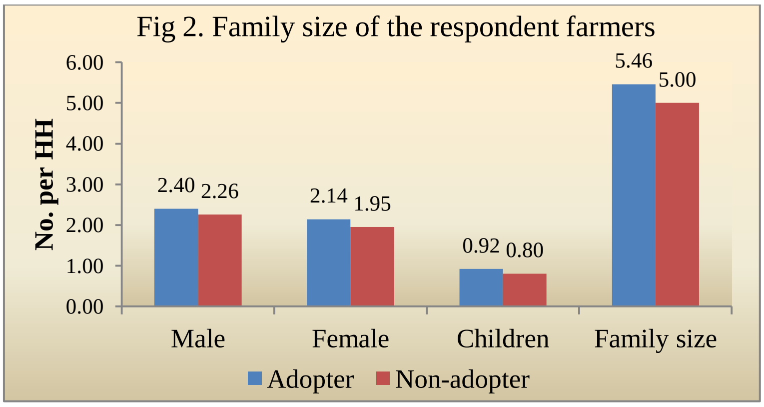


Education: On the basis of education level, the literacy status of the respondent farmers has been grouped into five categories. The categories are (1) illiterate, (2) primary, (3) secondary, (4) higher secondary, and (5) degree & above. Information on the educational levels of the respondents is presented in Table 1. In the case of adopters, the majority of them (41.5%) had secondary level education followed by primary level (20.7%) and higher secondary level (17%). Similarly, most non-adopters (31.5%) were found with maximum years of schooling from VI to X followed by primary level of education. Overall data shows that the level of education was higher for adopters than that of non-adopters in the study areas.

Table 1. Distribution of respondent farmers according to literacy level

Level of education	Adopter (n=135)		Non-adopter (n=270)	
	N	%	N	%
Illiterate	11	8.1	34	12.6
Primary (Class I-V)	28	20.7	82	30.4
Secondary (Class VI-X)	56	41.5	85	31.5
Higher secondary	23	17.0	22	8.1
Degree & above	17	12.6	47	17.4

Family size: Family size included the number of adult male, adult female and children in the respondent households. Average family size among the sample farmers was presented in Fig 2. Average family size was 5.46 and 5.00 for adopter and non-adopter farmers, respectively. The average number of male and female was 2.40 and 2.14 for adopter farmers, whereas these were 2.26 and 1.95 for non-adopter farmers, respectively. Family size of adopter farmers was slightly bigger than non-adopter farmers in the study areas.



Occupation: The work for which a household head is engaged throughout the year as a main source of income is known as his primary occupation. The majority of people in the rural areas adopt agriculture as their main occupation. The respondent farmers were engaged in various types of occupation. Table 2 shows that most of the adopter and non-adopter farmers had single occupation and crop farming was the dominant among different occupations. It also appeared that business was the second most important secondary occupation of both adopters (25.2%) and non-adopters (19.6%) of CA farmers. Nearly 3% of the farmers among adopters and non-adopters had service as secondary occupation in the study areas. Other secondary occupations of both categories of farmers were reported to be as service provider of agricultural machineries, livestock & fisheries and van/rickshaw (non-motorized or motorized three wheeler) puller.

Table 2. Distribution of respondent farmers according to occupation

Occupation type	Adopter (n=135)		Non-adopter (n=270)	
	Primary occupation	Secondary occupation[3]	Primary occupation	Secondary occupation
Crop farming	93.3	5.9	94.8	5.9
Business	2.2	25.2	0.4	19.6
Service	1.5	3.0	2.2	2.6
Service provider	--	6.7	--	3.3
Livestock & fisheries	--	1.5	--	3.3
Van/rickshaw puller	--	4.4	--	2.6
Others	3.0	14.1	1.5	6.0
All category	100	60.8	100	44.4

Farming experience: Farming experience is an important factor that ensures farm productivity. Farmers who have more experience in farm operations generally attain higher levels of technical efficiency (Miah et al., 2014). The average experience of crop farming was estimated at 17.9 years for adopters and 21.7 years for non-adopters. It was found that 40% of adopter and 27% of non-adopter belonged to the category 3-10 years of farming experience. Again, 31.1% of adopter and 30.4% of non-adopter belonged to the group 11-20 years'

[3] A secondary occupation of a farmer is carried out alongside the occupation that is regarded as the main employment or source of income.

experience in crop farming. Small number of adopter (3.0%) and non-adopter (7.4%) fell in the group 40-60 years of experience in farming in the study areas (Table 3).

Table 3. Distribution of respondent farmers according to farming experience

Experience level (year)	Adopter (n=135)		Non-adopter (n=270)	
	N	Percent	N	Percent
03-10	54	40.0	73	27.0
11-20	42	31.1	82	30.4
21-30	20	14.8	55	20.4
31-40	15	11.1	40	14.8
41-60	4	3.0	20	7.4
Average experience	17.9 years		21.7 years	

Training received: Training is a most important tool for acquiring knowledge about technology. It can increase farmer's skill regarding production practices and related aspects. It is revealed from Table 4 that about 64% of the adopters and 51% of non-adopters received training on different aspects of crop cultivation. It implies that a good percentage of the respondent farmers are still lacking in appropriate training on crop production. Most of the CA adopting farmers (47.4%) and non-CA farmers (38.9%) received 1-3 nos. of training on different aspects of crop production. Again, about 9% adopters and 10% non-adopters had 4-6 times training on crop production.

Table 4. Distribution of farmers according to training received on crop cultivation

Training received (No./life time)	Adopter (n=135)		Non-adopter (n=270)	
	N	Percent	N	Percent
1 - 3 Nos.	64	47.4	105	38.9
4 - 6 Nos.	12	8.9	27	10.0
7-10 Nos.	6	4.4	4	1.5
11-15 Nos.	4	3.0	2	0.7
Total	86	63.7	138	51.1

It is revealed from Table 5 that most of the adopters (79.1%) and non-adopters (82.6%) received training from Department of Agriculture Extension (DAE) followed by different research institutes (13-16.3%). A small percentage of trained adopters and non-adopters also received training from IPM club and various NGOs. Before dissemination of CA technologies, the project personnel under CA project provided training on various aspects of CA technologies. Hence, more than 9.3% adopters and 7.9% non-adopters received training from CA project. It is important to state that most CA farmers took lessons on CA technologies from local service providers in the study areas.

Table 5. Distribution of respondent farmers according to training agencies

Training agencies	Adopter (n=86)		Non-adopter (n=138)	
	N	Percent	N	Percent
1. DAE	68	79.1	114	82.6
2. Research institutes	14	16.3	18	13.0
3. IPM club	12	14.0	8	5.8
4. CA project	8	9.3	11	7.9
5. NGOs	5	5.8	6	4.3

Farm size: Land is the most important asset for farm household because farm families mostly depend on the land. Farm size is computed by the entire land area operated by the respondent farmers. It included the area of cultivated land owned with the area rented in and mortgage in from others and subtracting the area rented out and mortgage out to others. It includes the homestead land (housing plot), orchard and pond.

The average farm size of the adopter and non-adopter farmers was 1.182 ha and 0.977 ha, respectively. The adopter farmers had the highest cultivated land which was about 0.656 ha followed by mortgaged in and rented in lands. Similar observation was found for non-adopter farmers (Table 6). It implies that the farmers of higher farm size are more incline to CA adoption.

Table 6. Land category and farm size of the respondent farmers

Land type	Adopter (n=135)		Non-adopter (n=270)	
	Area (ha)	SD	Area (ha)	SD
1. Own cultivable land	0.656	1.087	0.620	0.929
2. Rented in	0.189	0.504	0.192	0.361
3. Rented out	0.049	0.318	0.062	0.555
4. Mortgaged in	0.195	0.332	0.110	0.239
5. Mortgaged out	0.011	0.063	0.025	0.150
6. Homestead	0.045	0.099	0.028	0.034
7. Pond	0.098	0.311	0.061	0.262
8. Orchard	0.059	0.142	0.052	0.144
Farm size*	**1.182**	**1.258**	**0.977**	**0.893**
Land under CA	0.320	0.391	--	--

**Farm size = (1+2+4+6+7+8) – (3+5)*

Annual household income: The average annual household income of the adopter and non-adopter farmers was Tk. 2,68,816 and Tk. 2,36,792, respectively. The highest share of income for both categories of farmers came from crops, livestock & poultry (15.9-16.7%) followed by business (13.2-15.2%), service (8.4-11.1%), fisheries (4.9-5.6%), wage labour (3.6-4.2%), and farm machineries (1.1-2.2%). However, the income from hiring out of farm machineries for adopter farmers was about double compared to non-adopting farmers in the study areas. About 3% of the total income of the non-adopter’s household came from foreign remittance which was totally absent for adopters’ households (Table 7).

Table 7. Annual household income of the respondent farmers

Income source	Adopter (n=135)		Non-adopter (n=270)	
	Tk./HH	% share	Tk./HH	% share
Crops	109553	40.8	99678	42.1
Livestock &poultry	42857	15.9	39647	16.7
Business	40926	15.2	31333	13.2
Service	29970	11.1	19783	8.4
Fisheries	13107	4.9	13187	5.6
Wage labour	9570	3.6	9937	4.2
Farm machinery	6007	2.2	2708	1.1
Crop residues	4029	1.5	2246	0.9
Foreign remittance	--	--	6863	2.9
Others	12797	4.8	11409	4.8
Total (Tk/year)	268816	100	236792	100

Organizational membership: Social participation is an indicator of respondent's likely exposure to new knowledge and improved decision making. There are many social organizations, such as Farmers' Cooperative Society, Youth Cooperative Society, School Committee, IPM/ICM Club, Mosque Committee, Bazaar Committee, and Union Council. Membership of these social organizations was considered as a measure for social participation.

Social participation of the respondent farmers is shown in Table 8. The total score achieved by adopter farmers (0.95) implied that the involvement of CA adopters in different societal organisations was more compared to non-adopters. The respondent adopters are involved more with Farmers' Cooperative Societies, Farmers' Association for CA and IPM/ICM club compared to non-adopters.

Table 8. Extent of association of the respondent farmers with social organizations

Societal organization	Adopter (n=135)		Non-adopter (n=270)	
	Mean score	SD	Mean score	SD
Farmers Cooperative Society	0.13	0.48	0.05	0.31
Youth Development Society	0.07	0.50	0.04	0.19
School Committee	0.03	0.21	0.03	0.18
IPM/ICM Club	0.27	0.72	0.17	0.60
Mosque Managing Committee	0.10	0.33	0.13	0.51
Market Managing Committee	0.02	0.15	0.03	0.19
Union Council	0.01	0.09	0.03	0.29
Farmers Association for CA	0.31	0.48	--	--
Total score	**0.95**	**1.22**	**0.48**	**1.05**

Note: Score for a specific organization ranged from 0 to 4. Total score ranged from 0 to 32.
Scores 0 and 4 mean the *lowest* and *highest* association with a specific organization respectively.

Innovative activities: It is expected that adopter farmers are more dynamic than that of non-adopters. Therefore, adopter farmers are likely to be tending more on various innovative activities. The higher score achieved by adopters implies that they were tending more on various innovative activities compared to non-adopters. Adopter farmers practiced innovative activities like use of compost, green manure, IPM technologies and artificial insemination more than that of non-adopters (Table 9).

Table 9. Extent of practicing innovative activities by the respondent farmers

Innovative activity	Adopter (n=135)		Non-adopter (n=270)	
	Mean score	SD	Mean score	SD
Use of green manure	0.67	0.98	0.29	0.71
Use of compost	1.05	1.00	0.42	0.81
Cultivating crops on *Ail*	0.06	0.34	0.05	0.30
Use of IPM technologies	0.49	0.86	0.29	0.70
Use of artificial insemination	0.74	0.97	0.37	0.77
Keeps bee in mustard field	0.06	0.34	0.00	0.06
Total score	**3.07**	**2.47**	**1.43**	**1.91**

Note: Score for a particular activity ranged from 0 to 2. Total score ranged from 0 to 12.
Scores 0 means *no use* and 2 means *frequent use* of an innovative activity.

Farmer's cosmopolitness: Cosmopolitness is the character of an individual for explaining his outer exposure towards the environment and the source of information. The increased cosmopolitness of an individual emphasizes the knowledge endowment and exposure as well as experience on the information received from different sources. It is expected that more cosmopolite farmers used more improved technologies compared to less cosmopolite farmers. Table 10 reveals that the total score achieved by adopting farmers in this regard was slightly higher than that of non-adopting farmers. It implies that both categories of farmers frequently visited Thana Sadar and district town. Most study areas were close to the Thana Sadar and district town and because of this reason the total score was more or less similar for two groups of farmers (Table 11).

Table 10. Extent of cosmopolitness by the respondent farmers

Place of visit	Adopter (n=135)		Non-adopter (n=270)	
	Mean score	SD	Mean score	SD
Thana Sadar	3.33	1.06	2.98	1.13
District level	2.48	1.06	2.14	1.08
Dhaka City	0.90	0.73	0.70	0.65
Foreign country	0.01	0.09	0.03	0.19
Total score	**6.72**	**2.17**	**5.84**	**2.20**

Note: Score for a particular place ranged from 0 to 4. Total score ranged from 0 to 12.
Scores 0 and 4 mean *no visit* and *frequent visit* in a specific place respectively.

Level of extension contact: Extension agents play an important role in technology dissemination. The Sub-Assistant Agriculture Officer (SAAO) of DAE is the key person to make contacts with the farmers for any kind of technology dissemination and crop related issues. In addition, farmers can gather up-to-date knowledge on overall crop production from different extension media, such as agriculture fair, booklets, leaflets, field day, demonstration plots, research institutes, and mass media. Table 11 reveals that the total score for adopters is higher than that of non-adopters implying that adopter farmers contact more with different extension media than that of non-adopters. Both adopter and non-adopter mostly contacted with DAE personnel and progressive farmer for gathering crop production related information in the study areas. In addition, they gathered knowledge through visiting agriculture fair and demonstration blocks.

Table 11. Extent of using information sources by the respondent farmers

Source of information	Adopter (n=135)		Non-adopter (n=270)	
	Mean score	SD	Mean score	SD
DAE personnel	3.41	0.92	3.09	1.09
Neighboring farmer	3.61	0.79	3.38	1.04
Television	1.80	1.35	1.26	1.18
Agriculture fair	1.38	1.08	0.96	0.96
Demonstration blocks	1.16	1.01	0.79	0.82
Daily Newspaper	0.70	1.18	0.56	1.11
Radio	0.19	0.61	0.08	0.36
Booklet/pamphlet, etc	0.29	0.78	0.14	0.47
Research Institutes	0.29	0.68	0.14	0.45
Field day	0.47	0.78	0.32	0.56
Total score	**13.30**	**4.88**	**10.73**	**4.16**

Note: Score for a specific source ranged from 0 to 4. Total score ranged from 0 to 40.
Scores 0 and 4 mean *no use* and *frequent use* of a specific source of information respectively.

3.2 Adoption Status of CA Technologies in the Study Areas

The existing level of CA technologies introduced in crop production, their level of adoptions, and the factors influenced farmers to adopt those technologies are discussed in the following sections.

3.2.1 Adoption status of minimum tillage operations

This section illustrates the minimum soil disturbance planter that was promoted or prescribed and compares those planter with current farmer practices. In the study areas, Versatile Multi-crop Planter (VMP) is being promoted by Murdoch University, Australia for crop establishment in minimum soil disturbance (Fig 3). BARI with the help of CIMMYT also promoted some minimum tillage planters in the study areas. Data presented in Table 12 shows that majority of the farmers belonged to adopter and non-adopter groups used full tillage operation by 2-WT for land preparation and 100% CA farmers used VMP for minimum soil disturbed crop establishment in single pass operation. The uses of Power Tiller Operated Seeder (PTOS) and country plough are rare in the study areas.

Respondent farmers were asked to give their opinion on intensive tillage in crop production. About 73% of the CA adopters and 26.3% non-adopters considered intensive tillage harmful for soil health and crop productivity. About 74% of the non-adopters considered intensive tillage beneficial to soil and crop yield. Such response from non-adopters might be due to lack of knowledge and mindset on minimum soil disturbance.

Fig 3. Tillage with versatile multi-crops planter

Table 12. Status of tillage/planting operations in the study areas

Tillage equipment/ planter	Adopter (*N=135*)		Non-adopter (*N=270*)	
	N	%	N	%
2WT (power tiller)	115	85.2	270	100
VMP	135	100	--	--
PTOS	1	0.7	--	--
Country plough	1	0.7	5	1.9

Both categories of farmers who responded in favor of minimum soil disturbing technologies mentioned various drawbacks of intensive tillage. Table 13 shows that more than 60% of the adopters and nearly 92% non-adopters gave the impression that soil fertility reduces due to intensive tillage. The emergence of enormous weeds in the crop field might be one of the causes of intensive tillage which was mentioned by 63.3% adopters and 11.3% non-adopters. Intensive tillage requires higher cost which was pointed out by 51% of the adopters and about 17% of non-adopters in the study areas. Loose soils are easily washed out during heavy rain or flood. Therefore, 47% of the adopters and 11.3% of non-adopters raised this issue due to intensive tillage. However, a good percentage (29-46%) of the adopters also mentioned that intensive tillage requires higher dose of fertilizers and irrigation.

3.2.2 Status of weed control

Weed control is an important task in crop production. It reduces competition between crop and weed for water, nutrients and light and ultimately increases crop productivity and farm profitability (Cudney et al., 2001). Evidence shows that 43-51% yield loss in rice has been occurred in the farmers' field due to poor weed control measure (Rashid et al., 2012).

However, the farmers in the study areas control weeds mainly by three different ways such as using herbicides, mechanical device and by hands. In many events, some farmers control weeds using more than one method in the same plot or crop or in different cropping seasons. The application of herbicides is more convenient means of weed control (Kumar et al., 2008; Mahajan et al., 2009) as it is cost-effective and swift (Santos, 2009; Mazid, 2010) and much productive and economic than that of hand weeding (Ahmed et al., 2001; Rashid et al., 2012). Therefore, weed control using herbicides is currently widespread in conventional cropping in the study areas. Data shown in Table 14 reveals that nearly 95% of the adopters and 88.1% of non-adopters controlled weeds through using different types of herbicides. Hand and mechanical weeding for rice is still an important method of weed control. Rice farmers used wetland weedier and manual labour for second time weed control prior to herbicide use. A good percentage (19.6-27.4%) of progressive farmers also used mechanical devices (e.g., wetland weedier) for controlling weeds.

Table 13. Farmers' perceptions on the intensive tillage of soil

Particular	Adopter (*N=135*)		Non-adopter (*N=270*)	
	N	%	N	%
Response on intensive tillage				
Harmful	98	72.6	71	26.3
Beneficial	37	27.4	199	73.7
Disadvantage of intensive tillage	*n=98*		*n=71*	
Reduce of soil fertility	59	60.2	65	91.5
Emergence of enormous weeds	62	63.3	8	11.3
Higher cost of tillage	50	51.0	12	16.9
Erosion of soil	46	46.9	8	11.3
Required higher fertilizer	45	45.9	2	2.8
Required higher irrigation	28	28.6	8	11.3
Loss of beneficial insects	4	4.1	5	7.0
Others*	2	2.0	4	5.6

Note: *Soil becomes hard, higher insects-diseases infestation, required higher seed, lower yield, etc.

Table 14. Mode of weed control in the study areas

Mode of weed control	Adopter (*N=135*)		Non-adopter (*N=270*)	
	N	%	N	%
1. Using herbicides	128	94.8	238	88.1
2. Hand weeding	73	54.1	204	75.6
3. Mechanical weeding	37	27.4	53	19.6

The average experience of farmers in using herbicides was 5.52 years for adopters and 5.47 years for non-adopters in the study locations. However, the highest percentage of the adopters and non-adopters fall into the experience group 7-10 years followed by experience group 4-6 years (Table 15).

In the recent years, off-farm activities have been increased to a great extent in the study areas as a result the scarcity of human labour has been arisen in crop farming. Hence, the main reason of using herbicides was the lack of human labour and reduces the cost of labour.

Table 15. Experience of farmers in using herbicides to control weeds

Range of experience	Adopter (*N=135*)		Non-adopter (*N=270*)	
	N	%	N	%
1-3 years	35	25.9	47	17.4
4-6 years	37	27.4	111	41.1
7-10 years	56	41.5	80	29.6
Average experience (year)	5.52		5.47	

More than 59% of the adopters and 73.3% non-adopters mentioned that the labour shortage and cost of labour is the main reason of using herbicides. The use of herbicides helps growing less weed in the field and also reduces the number of weeding for the next crop. About 44.4% of the adopters and 23.0% non-adopters opined to be the cause of using herbicides. Required comparatively less time to control weeds was another reason for using herbicides. The other causes of herbicides use mentioned by adopters and non-adopters were getting higher yield, control enormous weeds easily, eradicate small weeds, established crop timely, and less attack of insect-pests (Table 16).

Table 16. Reasons of using herbicides to control weeds

Reason of herbicides use	Adopter (*N=135*)		Non-adopter (*N=270*)	
	N	%	N	%
1. Lack of labour/reduce labour cost	80	59.3	198	73.3
2. Emergence of less weeds	60	44.4	62	23.0
3. Required less time	54	40.0	22	8.1
4. Getting higher yield	16	11.9	29	10.7
5. Control enormous weeds easily	8	5.9	39	14.4
6. Eradicate small weeds	5	3.7	28	10.4
7. Established crop timely	3	2.2	2	0.7
8. Less attack of insect-pests	2	1.5	4	1.5
9. Others*	4	3.0	3	1.1

*Established crop timely, higher germination of seeds, etc.

The respondent farmers who did not use herbicides to control weeds mentioned various reasons in favour of not using herbicides. A small percentage of the CA and non-CA farmers did not use herbicides because they thought that established crop becomes weak, needs more fertilizer, deteriorates soil fertility, and dies beneficial insects due to use herbicides (Table 17).

Table 17. Reasons of not using herbicides to control weeds

Reason of not using herbicides	Adopter (*N=135*)		Non-adopter (*N=270*)	
	N	%	N	%
1. Crops become weak/less yield	2	1.5	21	7.8
2. Needs more fertilizer	3	2.2	4	1.5
3. Deteriorates soil fertility	--	--	9	3.3
4. Dies beneficial insects	--	--	3	1.1

3.2.3 Adoption status of crop residue retention

A good section of the adopting and non-adopting farmers in the study areas retained crop residues in the field after harvesting of rice (*Boro &Aman*), wheat, and maize to a varied extent (Figs 4 & 5). Table 18 reveals that the average heights of crop residues kept by the CA farmers were 6.3″, 6.2″, 10.5″ and 18.8″ for *Boro, Aman*, wheat and maize, respectively. Although the average residue heights kept by the CA farmers for *Boro* and *Aman* rice were more or less equal to the heights kept by the non-CA farmers, the residue heights for wheat and maize were higher for non-CA farmers in the study areas.

Fig 4. Residue retention after rice harvest, Rajshahi

Fig 5. Lentil cultivation with crop residue, Rajshahi

Table 18. Amount of crop residues retained in the field

Particular	Boro rice	Aman rice	Wheat	Maize
A. Adopter	*n=98*	*n=135*	*n=135*	*n=47*
Minimum (inch)	2	4	5	12
Maximum (inch)	12	10	18	24
Mean (inch)	6.3	6.2	10.5	18.8
B. Non-adopter	*n=213*	*n=270*	*n=185*	*n=76*
Minimum (inch)	2	2	6	12
Maximum (inch)	12	12	20	24
Mean (inch)	6.2	6.2	11.4	21.1

The respondent farmers in the study areas retained crop residues for many reasons. Improving the soil fertility was the prime reason for keeping a certain portion of crop residue stated by both CA (95.6%) and non-CA farmers (97%). Many farmers opined that when rice or wheat plants are slashed above the soil keeping some residues, the straw remains clean for animal feed. Therefore, a good percentage of both adopter and non-adopters in the study areas stated that they kept crop residue in order to remain straw clean for animal. About 12% CA farmers mentioned that the retention of crop residue ensures less fertilizers application which was might be due to increased fertility. A good percentage of both CA and non-CA farmers also stated some other reasons such as threshing of crops become easy (6.7-11.1%), transporting harvests become easy (3.7-5.6%), and reduction of soil & nutrients erosion (Table 19).

There are trade-offs in the role of residues in i) boosting grain yields, ii) providing a resource for livestock feed and cooking, and iii) providing ground cover to reduce erosion potential (Komarek, 2013). However, the respondent farmers in the study areas used harvested crop residues (straw) in many purposes. Data presented in Table 20 reveals that the highest percentage of both CA and non-CA farmers used rice straw as animal feed (83.0-88.7%) followed by selling to others (7.9-15.2%). Similarly, pulse straw/bran was mostly used as animal feed (49.3-55.1%) and fuel for cooking (42.1-43.8%). In the case of wheat, maize and mustard crops, the highest proportion of harvested residues (92.3-100%) were used as household fuel for cooking purpose. However, a small portion of the crop residues was used as mulch for growing other crops.

Table 19. Reasons for retaining crop residues in the field

Reasons for retaining crop residue	Adopter (*N=135*)		Non-adopter (*N=270*)	
	N	%	N	%
1. Improve soil fertility	129	95.6	262	97.0
2. Straw remains clean/good feed	20	14.8	59	21.9
3. Crop harvest needs less labour	19	14.1	44	16.3
4. Reduce the amount of fertilizer uses	16	11.9	2	0.7
5. Threshing crops become easy	9	6.7	30	11.1
6. Transporting harvests become easy	5	3.7	15	5.6
7. Increases next crop's yield	8	5.9	--	--
8. Reduces soil & nutrients erosion	3	2.2	4	1.5
9. Others*	8	5.9	10	3.7

Note: *Day labourer does not want to cut rice just up the soil, habitat of beneficial birds, climbing means for lentil crop, preserve soil moisture, straw dry early, and emergence of less weeds/grass.

Table 20. Percent use of harvested crop residues in the study areas

Type of use	Boro rice	Aman rice	Wheat	Maize	Pulses	Mustard
A. Adopter	*n=96*	*n=135*	*n=135*	*n=46*	*n=71*	*n=11*
Fodder	87.18	88.70	3.04	1.95	49.30	--
Fuel	3.39	1.56	93.55	93.70	42.11	100
Mulch	1.25	1.81	2.37	4.35	7.46	--
Sale	8.18	7.93	1.04	--	1.13	--
B. Non-adopter	*n=215*	*n=270*	*n=187*	*n=77*	*n=122*	*n=37*
Fodder	83.00	84.74	0.70	--	55.12	1.22
Fuel	1.60	1.17	92.30	97.40	43.81	96.08
Mulch	0.16	0.06	6.68	1.30	1.07	--
Sale	15.24	14.03	0.32	1.30	--	2.70

3.2.4 Adoption status of crop rotations

Both CA and non-CA farmers in the study areas adopted crop rotations over the years. Table 21 shows that half of the CA farmers and 34.4% of the non-CA farmers adopted crop rotations over the years. In principle, CA farmers must practice suitable crop rotations over the years, but in practice about 50% CA farmers did not practice crop rotations at all. This might be happened because most of the CA farmers are passing 1st year and 2nd year of their CA practice. However, they have intention to follow suitable crop rotations in the near future.

Table 21. Status of adoption of crop rotations in the study areas

Status of crop rotation	Adopter (*n=135*)		Non-adopter (*n=270*)	
	N	%	N	%
Adopted	68	50.4	93	34.4
Not adopted	67	49.6	177	65.6

A wide range of cropping patterns has been practiced by the respondent farmers in the study areas (Appendix 1). The major cropping patterns such as *Lentil-Boro-T.Aman*; *Wheat-Jute-T. Aman*; and *Mustard-Boro-T.Aman* were practiced by most of the CA and non-CA farmers (Tables 22 & 23). The other important patterns were reported as *Wheat-Maize-T.Aman*; *Wheat-Fallow-T.Aman* and *Wheat-Mungbean-T.Aman* (Fig-6). However, many CA farmers started introducing pulse crops in the cropping patterns. Crop rotations with leguminous crops have the potential to increase soil nitrogen concentration through biological nitrogen fixation (Giller, 2001).

Table 22. Crop rotations followed by CA adopter farmers in the study areas

Current year (n=68)			Previous year (n=68)			Two year before (n=68)		
CP*	N	%	CP*	N	%	CP*	N	%
1	16	23.5	4	15	22.1	4	18	26.5
2	9	13.2	2	9	13.2	2	11	16.2
3	8	11.8	1	6	8.8	1	6	8.8
4	6	8.8	3	6	8.8	3	4	5.9
5	5	7.4	6	4	5.9	5	3	4.4
6	4	5.9	7	3	4.4	6	3	4.4
Others	20	29.4	Others	25	36.8	Others	23	33.8

*Cropping pattern (CP):
1. Lentil-Boro-T.Aman; 2. Wheat-Jute-T.Aman; 3. Wheat-Maize-T.Aman; 4. Mustard-Boro-T.Aman; 5. Wheat-Fallow-T.Aman; 6. Wheat-Mungbean-T.Aman; 7. Potato-Maize-T.Aman

Table 23. Crop rotations followed by non-adopter farmers in the study areas

Current year (n=93)			Previous year (n=93)			Two year before (n=93)		
CP*	N	%	CP*	N	%	CP*	N	%
1	17	18.3	4	15	16.1	4	20	21.5
2	17	18.3	1	9	9.7	1	11	11.8
3	13	14.0	3	8	8.6	3	9	9.7
4	8	8.6	8	8	8.6	2	8	8.6
5	6	6.5	6	7	7.5	5	7	7.5
6	6	6.5	2	6	6.5	8	5	5.4
7	4	4.3	5	6	6.5	6	4	4.3
Others	21	22.6	Others	34	36.6	Others	29	31.2

*Cropping pattern (CP):
1. Lentil-Boro-T.Aman; 2. Wheat-Fallow-T.Aman; 3. Wheat-Jute-T.Aman; 4. Mustard-Boro-T.Aman; 5. Wheat-Maize-T.Aman; 6. Lentil-Fallow-T.Aman; 7. Onion-Jute-T.Aman; 8. Fallow-Boro-T.Aman

Figure 6. Suitable cropping pattern

Wheat — Mungbean — Transplanted Aman

For many reasons, some respondent farmers in the study areas have been practicing crop rotations year after year. Table 24 shows that 25.2% of the CA adopters and 19.6% of the non-adopters have been practicing suitable crop rotations from long past, because they know well that monoculture reduces crop productivity. Crop rotations can improve soil organic matter to a large extent and it has immense effect on soil physical and chemical properties and thereby on crop productivity (Alam et al., 2016a; Ranamukhaarachchi et al., 2005). Hence, about 13.3% adopting farmers and 4.4% non-adopting farmers practiced crop rotations for maintaining soil fertility. Besides, the cultivation of pulse (lentil) is highly remunerative to the farmers. Many farmers (4.4-7.4%) are practicing crop rotations introducing pulse crops in the study areas. Some sampled farmers also thought that suitable crop rotations can reduce the incidence of insects and diseases (Table 24).

Table 24. Reasons for practicing crop rotation

Reasons	Adopter *(n=135)*		Non-adopter *(n=270)*	
	N	%	N	%
1. Monoculture reduces crop yield	34	25.2	53	19.6
2. Maintenance of soil fertility	18	13.3	12	4.4
3. Higher price of pulses (lentil)	10	7.4	12	4.4
4. Less incidence of insects & diseases	5	3.7	5	1.9
5. Others*	2	1.5	--	--

Note: Other includes less emergence of grass & unable to cultivate onion by VMP

3.2.5 Rate of adoption of CA technologies

The scientists of Murdoch University, Australia with the funding support from ACIAR and in collaboration with BAU, BARC, BARI, BRRI and NGOs have disseminated some CA technologies in the study areas during 2012-2015. During that period many farmers observed the benefits of CA technologies and gradually adopted these technologies. This adoption process is still on-going in the study areas. However, the survey results showed that on an average 20.3% farmer from Rajshahi and 10.1% farmer from Thakurgoan districts adopted Versatile Multi-crop Planter (VMP) for crop establishment in minimum disturbed soil (e.g., strip planting). Bed planting system can't be considered as CA system since it disturbed soils to a great extent (Haque et al., 2017). In Rajshahi district, only 4.7% of the farmers used bed planter to prepare beds for cultivating crops, whereas 2.8% farmers established crops under zero tillage. A large portion (59.8-73.6%) of the farmers from both areas retained crop residues in the crop fields. Again, about 39% of the farmers practiced crop rotations in the study areas (Table 25).

Table 25. Rate of adoption of conservation agriculture technologies

CA technology	Rajshahi		Thakurgoan		Both area	
	N	% adoption	N	% adoption	N	% adoption
Total farm households	316	--	348	--	664	--
1. Minimum tillage	88	27.8	35	10.1	117	18.6
Strip planting with VMP	*64*	*20.3*	*35*	*10.1*	*99*	*14.9*
Tillage with bed planter	*15*	*4.7*	--	--	*9*	*2.3*
Zero tillage	*9*	*2.8*	--	--	*9*	*1.4*
2. Crop residue retention	189	59.8	256	73.6	445	67.0
3. Suitable crop rotation	112	35.4	146	42.0	258	38.9

3.2.6 Factors influencing the adoption of CA technologies

The adoption of CA technologies promoted in the study areas was likely to be influenced by different socio-economic factors. Different factors such as age, education, availability of RCT planter (VMP), extension contract and innovativeness had significant influence on the adoption of CA technologies in the study areas (Table 26).

The marginal effects of the variables determining adoption of CA technologies are presented in Table 27. Age of the farmer had significant influence on the adoption of CA technologies implying that the probability of adoption of the CA technologies decreases with the increase of farmers' age. It means that young farmers are the most adopters of CA technologies.

Table 26. Maximum likelihood estimates of variable determining adoption of CA technologies among respondent farmers

Explanatory variable	Coefficient	SE	z-statistic	Probability
Constant	-2.9595***	0.6724	-4.40	0.000
Age (year)	-0.0170**	0.0068	-2.49	0.013
Education (year of schooling)	-0.0649***	0.0233	-2.79	0.005
Household size (No./HH)	0.0523	0.0415	1.26	0.208
LnFarm size (decimal)	0.1045	0.1217	0.86	0.391
Societal membership (wt. score) (Scale,0-4; 0= No membership, 4= Executive member)	0.1241	0.0817	1.52	0.129
Innovativeness (wt. score) (Scale,0-2; 0= no involvement, 2= involved)	0.1052***	0.0391	2.69	0.007
Extension contract (wt. score) (Scale,0-4; 0= no contact, 4= regular contact)	0.0810***	0.0250	3.24	0.001
Availability of VMP (score) (Scale,0-4; 0= not available, 4= plenty)	1.4884***	0.1594	9.34	0.000
Training (No./life time)	0.0136	0.0332	0.41	0.683
Cosmopolitness (Score)	-0.0430	0.0426	-1.01	0.313

Note: Dependent variable = CA technology adoption (Adopter = 1, Non-adopter = 0)
No. of observation = 405; LR chi-square (10) = 205.94; Log likelihood = -154.82; Pseudo R^2 = 0.3994
'***' & '**' represent significant at 1% and 5% level respectively
Higher score value represents the higher probability of CA technology adoption

Usually, education has positive influence on new technology adoption (Miah et al., 2013-15; Yokouchi and Saito, 2016; Miah et al., 2015). In this study, education had significant negative impact on the adoption of CA technologies implying that the probability of adoption of CA technologies decreases with the increase of the year of schooling. It means that low educated farmers are the most adopters of CA technologies compared to higher educated farmers in the study areas. Marginal coefficient reveals that if the year of schooling decreases by 100%, the probability of adopting CA technologies would be increased by 2.02%. It is expected that the impact of education will be significantly positive if CA technology disseminates properly in the study areas in future (Table 27).

Majority of the farmers in the study areas are unable to purchase a 2WT along with a VMP for crop establishment and practicing of CA. On the other hand, farmer's shallow knowledge on the advantage of minimum tillage and CA influences farmers not to adopt CA technology. In these circumstances, the availability of VMP in the locality is a crucial factor that highly influences farmers to adopt CA technology due to its demonstration effects and LSP's promotional activities. The marginal coefficient of VMP availability is positive and highly significant implying that the adoption probability of CA technologies would be increased by 46.38%, if the availability of VMP is increased by 100% (Table 27).

The sampled farmers' contact with different extension personnel such as Agriculture Officer, Sub Assistant Agriculture Officer, BARI scientist and neighbouring farmers had a positive and highly significant relationship with the probability of adopting CA technologies. Probit estimate also shows that there is a positive and significant relationship between CA technology adoption and extension contact. The probability of adopting CA technologies will be increased by 2.52%, if the extension contact is increased by 100% (Table 27).

Progressive farmers always tend to adopt new technology. The marginal coefficient of innovativeness is positive and significant at 1% level. If the aforesaid variable is increased by 100%, the probability of adoption of the CA technologies would be increased by 3.28% (Table 27).

Table 27. Marginal effect of the variables determining adoption of CA technologies among respondent farmers

Explanatory variable	Dy/dx	SE	z-statistic	Probability
Age (year)	-0.0053**	0.0022	-2.47	0.014
Education (year of schooling)	-0.0202***	0.0072	-2.80	0.005
Household size (No./HH)	0.0163	0.0129	1.26	0.208
LnFarm size (decimal)	0.0326	0.0377	0.86	0.388
Societal membership (wt. score) (Scale,0-4; 0= No membership, 4= Executive member)	0.0387	0.0256	1.51	0.131
Innovativeness (wt. score) (Scale,0-2; 0= no involvement, 2= involved)	0.0328***	0.0122	2.69	0.007
Extension contract (wt. score) (Scale,0-4; 0= no contact, 4= regular contact)	0.0252***	0.0078	3.24	0.001
Availability of VMP (score) (Scale,0-4; 0= not available, 4= plenty)	0.4638***	0.0473	9.81	0.000
Training (No./life time)	0.0042	0.0104	0.41	0.684
Cosmopolitness (Score)	-0.0134	0.0133	-1.01	0.313

Note: '***' & '**' represent significant at 1% and 5% level respectively

3.3 Impact of CA Technologies on Input Use, Productivity and Profitability

CA technologies have some more advantages in crop cultivation compared to the conventional method of cultivation in terms of efficient inputs-use, cost saving and higher profitability. Singh et al. (2011) evaluated the superiority of CA over conventional methods of cultivation in India. However, CA technologies also performed better in cultivating various crops such as lentil, maize, mustard, rice and wheat in Bangladesh. The impacts of CA technologies on input use, crop yield and farm profitability are discussed in the following sections.

3.3.1 Lentil cultivation

In lentil cultivation, strip planting by minimum soil disturbing planter, e.g., VMP saved significant amount of human labour in land preparation, seeding operation; and reduced the use of seed. Due to higher yield (28.24%), crop harvesting and threshing need additional labour for CA farmer. However, CA farmers used higher amounts of manures and fertilizers except DAP compared to non-CA farmers (Table 28).

Besides labour saving, the adoption of CA also helped in saving to the extent of expenditures on land preparation (Tk. 2414/ha), lentil seed (Tk. 722/ha), and irrigation cost (Tk. 115/ha). The total variable cost (VC) of cultivation was slightly higher (Tk. 255/ha) for CA farmers because of higher use of manure, fertilizers, pesticides, herbicides and higher cost for crop threshing. However, the total cost of lentil cultivation was 4.68% higher for CA farmers over non-CA farmer which was due to higher fixed cost (lease value of land) in the study areas (Table 29).

Table 28. Input saving in lentil cultivation by CA adopters over non-adopters

(Figure per ha)

Inputs	Adopter (n=51)		Non-adopter (n=102)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
Labour (Man-day)	41.67	14.03	43.93	19.67	-2.26	0.4146
Land preparation	0.00	0.00	3.21	1.20	-3.21***	0.0000
Seed sowing	0.00	0.00	1.41	1.11	-1.41***	0.0000
Weeding	8.10	12.53	9.39	16.23	-1.29	0.5874
Irrigating	1.19	1.46	1.10	1.42	0.09	0.7051
Fertilizing	2.04	1.13	2.02	1.13	0.03	0.8891
Harvesting	28.94	8.35	26.29	8.17	2.65*	0.0653
Threshing	1.40	1.98	0.52	1.60	0.88***	0.0076
Seed (kg)	39.92	4.72	47.11	7.18	-7.19***	0.0000
FYM (kg)	1616	2042	1430	2216	186.00	0.6069
Fertilizers						
Urea (kg)	56.30	38.69	43.14	42.47	13.16*	0.0575
TSP (kg)	100.63	50.07	81.32	62.84	19.32**	0.0415
MoP (kg)	56.04	29.44	52.84	37.94	3.20	0.5671
DAP (kg)	41.27	54.34	45.23	54.82	-3.96	0.6726
Gypsum (kg)	57.98	40.79	32.23	45.51	25.75***	0.0006
Boron (kg)	4.86	3.62	3.15	3.74	1.71***	0.0071
Zinc (kg)	3.93	4.17	2.94	4.66	1.00	0.1841

Note: Figures with negative sign in mean difference column indicate the amount of input saving by CA adopters over non-adopters, while non-negative figures indicate additional amount of input.
*'***', '**' and '*' indicate significant at 1%, 5% and 10% level.*

Table 29. Input cost saving in lentil cultivation by CA adopters over non-adopters

(Figure in Tk/ha)

Input cost	Adopter (n=51)		Non-adopter (n=102)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
A. Variable cost (VC)	39291	8743	39036	12444	255	0.8836
Land preparation	3179	357	5593	1581	-2414***	0.0000
Human labour	10018	3298	10634	4656	-615	0.3473
Seed	4717	625	5440	1050	-722***	0.0000
FYM	1267	1610	1130	1718	137	0.6283
Fertilizers	7695	5956	6427	6654	1268	
Urea	*989*	*687*	*757*	*747*	*231**	*0.0591*
TSP	*2839*	*1542*	*2304*	*1945*	*535**	*0.0669*
MoP	*899*	*483*	*823*	*589*	*77*	*0.3921*
DAP	*1325*	*1822*	*1442*	*1828*	*-117*	*0.7097*
Gypsum	*541*	*401*	*310*	*444*	*231****	*0.0016*
Boron	*628*	*485*	*420*	*501*	*208***	*0.0152*
Zinc	*474*	*536*	*371*	*600*	*103*	*0.2855*
Weed control	709	996	128	458	581***	0.0002
Plant protection	2012	1319	1793	1489	219	0.3562
Irrigation	1080	1482	1195	1613	-115	0.6615
Threshing	8615	2402	6697	2557	1917***	0.0000
B. Fixed cost (FC)	29890	4364	27053	2426	2837***	0.0000
Lease cost of land	29890	4364	27053	2426	2837***	0.0000
C. Total cost (VC+FC)	69181	11633	66089	14013	3092	0.1511

Note: Figures with negative sign in mean difference column indicate the amount saving by CA adopters over non-adopters, while non-negative figures indicate additional amount.
*'***', '**' and '*' indicate significant at 1%, 5% and 10% level.*

Even there were the lower selling price of grain (lentil) and straw, the CA farmers in the study areas obtained significantly higher gross (25.7%) and net income (47.3%) from lentil cultivation compared to non-CA farmer which was because of higher yield. The benefit cost ratio over total cost was also more than 19.7% higher for adopters (Table 30).

Table 30. Profitability differential in lentil cultivation-adopters vs. non-adopters

(Figure in Tk/ha)

Particular	Adopter (n=51)		Non-adopter (n=102)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
A. Gross return (GR)	164153	35645	130577	36443	33576***	0.0000
Grain yield (t/ha)	1.68	0.33	1.31	0.35	0.37***	0.0000
Sale price (Tk/ton)	95417	4484	96630	5545	-1213	0.1484
Income from grain	161299	35679	127160	36313	34138***	0.0000
Value of straw	2855	532	3417	1119	-562***	0.0000
B. Cultivation cost						
Fixed cost (FC)	29890	4364	27053	2426	2837***	0.0000
Variable cost (VC)	39291	8743	39036	12444	255	0.8836
Total cost (TC)	69181	11633	66089	14013	3092	0.1511
Gross margin (GR-VC)	124862	30955	91541	27613	33321***	0.0000
Net return (GR-TC)	94972	28139	64488	26336	30484***	0.0000
C. Benefit cost ratio						
Over VC	4.18	0.77	3.35	0.65	0.83***	0.0000
Over TC	2.37	0.35	1.98	0.31	0.40***	0.0000

Note: Figures with negative sign in mean difference column indicate the amount saving by CA adopters over non-adopters, while non-negative figures indicate additional amount.
*'***' indicate significant at 1% level.*

3.3.2 Maize cultivation

The adopters in the study areas used 34.1% less human labour, 7.7% less amount of seed and 50.9% less amount of FYM for maize cultivation than that of non-adopters. The saved number of labour was mostly attributed from land preparation, seed sowing, weeding and irrigation. CA farmers used higher amounts of chemical fertilizers compared to non-CA farmers. Conversely, non-CA farmers used significantly higher amount of FYM in maize cultivation. Again, CA farmers used more human labour in fertilizer application, crop harvesting and cob threshing than that of non-CA farmers (Table 31).

Strip planting by VMP reduced the cost of land preparation and seeding (simultaneously) of around 60%, 35% in human labour, 5% in seed, 44% in FYM, 31% in plant protection, and 23% in irrigation. The total variable cost (VC) and fixed cost (FC) of maize cultivation were 16% and 9.3% lower for CA farmers compared to non-CA farmers, respectively (Table 32).

The productivity of a crop depends on many factors such as time of sowing, seed quality, variety, crop management, weather, rate of manure and fertilizer use, inherent soil fertility, and so on. However, the adopters of CA technologies received 4.91% less yield compared to non-adopters. It was happened because non-adopter farmers used manures and fertilizers more than that of adopting farmers in the study areas. Even receiving the higher yield, non-adopters received less gross (10.2%) and net return (35.4%) due to lower grain price and higher cost of cultivation. The reason of getting lower price might be due to distressed sell of grain by most of the non-adopters (Table 33).

Table 31. Input saving in maize cultivation by CA adopters over non-adopters

(Figure per ha)

Inputs	Adopter (n=13)		Non-adopter (n=42)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
Labour (Man-day)	42.14	18.44	63.98	17.78	-21.84***	0.0013
Land preparation	0.00	0.00	2.69	0.97	-2.69***	0.0000
Seed sowing	0.00	0.00	12.63	3.89	-12.63***	0.0000
Weeding	9.67	15.24	16.96	14.15	-7.29	0.1420
Irrigation	3.42	1.59	4.53	2.11	-1.11*	0.0526
Fertilizing	1.93	0.58	1.72	1.06	0.21	0.3610
Harvesting	22.85	2.93	22.70	5.70	0.14	0.9054
Threshing	4.27	6.95	2.74	6.53	1.53	0.4910
Seed (kg)	18.34	2.36	19.88	2.41	-1.53*	0.0554
FYM (kg)	3591	3269	7308	5256	-3717***	0.0044
Fertilizers						
Urea (kg)	365.00	86.00	276.00	59.00	89.00***	0.0032
TSP (kg)	212.69	85.53	191.79	67.72	20.90	0.4312
MoP (kg)	205.87	38.59	198.48	67.40	7.39	0.7233
DAP (kg)	8.64	31.14	4.48	20.45	4.16	0.6578
Gypsum (kg)	73.97	46.13	31.72	48.15	42.26***	0.0095
Boron (kg)	7.33	4.48	4.31	5.41	3.02*	0.0549
Zinc (kg)	6.78	3.69	3.69	4.81	3.09**	0.0216

Note: Figures with negative sign in mean difference column indicate the amount of input saving by CA adopters over non-adopters, while non-negative figures indicate additional amount of input.
*'***', '**' and '*' indicate significant at 1%, 5% and 10% level.*

Table 32. Input cost saving in maize cultivation by CA adopters over non-adopters

((Figure in Tk/ha)

Input cost	Adopter (n=13)		Non-adopter (n=42)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
A. Variable cost (VC)	49855	7527	59323	10161	-9468***	0.0012
Land preparation	2858	568	7046	1286	-4189***	0.0000
Human labour	10908	4246	16760	4879	-5852***	0.0004
Seed	6879	1091	7225	1161	-347	0.3356
FYM	2579	2341	4627	2935	-2048**	0.0159
Fertilizers						
Urea	5918	1398	4522	969	1396***	0.0040
TSP	5051	2206	4730	1686	321	0.6354
MoP	3247	631	3123	1063	124	0.6072
DAP	225	810	112	511	113	0.6432
Gypsum	631	401	263	400	368***	0.0089
Boron	1034	676	580	765	454*	0.0523
Zinc	851	476	478	635	373**	0.0318
Weed control	829	815	210	399	620**	0.0192
Plant protection	1242	514	1787	1351	-546**	0.0353
Irrigation	3956	1257	5097	1928	-1141**	0.0184
Threshing	3648	1475	2763	813	884*	0.0577
B. Fixed cost (FC)						
Lease value of land	22263	2589	20209	3117	2054**	0.0258
C. Total cost (TC)	72118	8445	79532	10218	-7414**	0.0148

Note: Figures with negative sign in mean difference column indicate the amount saving by CA adopters over non-adopters, while non-negative figures indicate additional amount.
*'***', '**' and '*' indicate significant at 1%, 5% and 10% level.*

Table 33. Profitability differential in maize cultivation-adopters vs. non-adopters

(Figure in Tk/ha)

Particular	Adopter (n=13)		Non-adopter (n=42)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
B. Gross return (GR)	130569	20910	117312	11104	13257**	0.0458
Grain yield (t/ha)	9.16	0.68	9.61	1.08	-0.45*	0.0833
Sale price (Tk/ton)	14058	2851	11979	1361	2079**	0.0235
Income from grain	127618	20962	114325	10956	13293**	0.0455
Value of straw	2951	365	2987	795	-36	0.8219
B. Cultivation cost						
Fixed cost (FC)	22263	2589	20209	3117	2054**	0.0258
Variable cost (VC)	49855	7527	59323	10161	-9468***	0.0012
Total cost (TC)	72118	8445	79532	10218	-7414**	0.0148
Gross margin (GR-VC)	80714	19010	57989	14337	22725***	0.0011
Net return (GR-TC)	58451	16880	37780	13658	20671***	0.0009
C. Benefit cost ratio						
Over VC	2.62	0.45	1.98	0.42	0.64***	0.0003
Over TC	1.81	0.23	1.48	0.23	0.34***	0.0003

Note: Figures with negative sign in mean difference column indicate the amount saving by CA adopters over non-adopters, while non-negative figures indicate additional amount.
*'***', '**' and '*' indicate significant at 1%, 5% and 10% level.*

3.3.3 Mustard cultivation

A significant amount of inputs was also saved in mustard cultivation under CA technologies. Although the reduced amount of total labour was insignificant, remarkable reduction was observed in land preparation and seed sowing. However, CA adopters could save mustard seed (2.09 kg/ha) and different chemical fertilizers to some extent (Table 34). The use of herbicides in controlling weeds is currently a common practice in the study areas. The adopting farmers used herbicides more than that of non-adopting farmers. Again, they used pesticides and irrigation low amount compared to non-adopters.

The adopters of CA technologies saved to the extent of expenditures on land preparation (46.6%), seed (15.6%), FYM (10.0%), fertilizers (4.9%), plant protection (32.4%), and irrigation (19.1%). Again, the cost of herbicides was 435% higher for adopters than non-adopters. Thus, about 12% variable cost was saved due to adoption of CA technologies in mustard production. The total cost of mustard cultivation was 9.8% lower for CA farmers over non-CA farmer (Table 35).

The total yield advantage was 18.75% higher for CA adopters over non-adopters. The cost advantage and yield advantage combined together brought up the total returns of adopters to around 21.3% higher than that of non-adopters in the study areas. The benefit-cost ratio over TC of adopters of CA technologies was 1.44 which was around 35% higher than that of the non-adopters in the study areas (Table 36).

Table 34. Input saving in mustard cultivation by CA adopters over non-adopters

(Figure per ha)

Inputs	Adopter (n=11)		Non-adopter (n=35)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
Labour (Man-day)	52.79	13.98	52.96	16.08	-0.18	0.9720
Land preparation	0.00	0.00	2.55	1.12	-2.55***	0.0000
Seed sowing	0.00	0.00	1.25	0.66	-1.25***	0.0000
Weeding	5.43	7.53	4.64	8.61	0.79	0.7739
Irrigation	1.23	0.79	1.63	1.16	-0.40	0.2099
Fertilizing	1.47	1.17	2.04	0.86	-0.58	0.1532
Harvesting	26.27	6.97	25.20	6.61	1.07	0.6583
Threshing	18.38	4.18	15.65	8.84	2.73	0.1707
Seed (kg)	7.89	1.33	9.99	4.22	-2.09**	0.0141
FYM (kg)	1746	2484	1675	2347	71.00	0.9340
Fertilizers						
Urea (kg)	88.42	31.84	97.67	52.35	-9.25	0.4845
TSP (kg)	65.30	49.02	92.07	72.07	-26.77	0.1745
MoP (kg)	44.00	25.25	46.40	28.32	-2.40	0.9728
DAP (kg)	68.85	38.66	53.25	61.82	15.60	0.3278
Gypsum (kg)	33.98	34.13	21.64	44.35	12.34	0.3228
Boron (kg)	5.15	3.74	2.78	4.34	2.38*	0.0935
Zinc (kg)	4.71	5.18	4.20	5.02	0.51	0.7783

Note: Figures with negative sign in mean difference column indicate the amount of input saving by CA adopters over non-adopters, while non-negative figures indicate additional amount of input.
*'***', '**' and '*' indicate significant at 1%, 5% and 10% level.*

Table 35. Input cost saving in mustard cultivation by CA adopters over non-adopters

(Figure in Tk/ha)

Inputs	Adopter (n=11)		Non-adopter (n=35)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
A. Variable cost (VC)	27825	6093	31635	9512	-3810	0.1302
Land preparation	3073	518	6092	1350	-3019***	0.0000
Human labour	12803	3471	13038	4142	-236	0.8534
Seed	645	111	764	289	-119*	0.0518
FYM	1364	1887	1515	2072	-151	0.8232
Fertilizers						
Urea	1502	545	1568	941	-66	0.7756
TSP	1629	1498	2492	2040	-863	0.1424
MoP	689	386	732	448	-43	0.7906
DAP	2094	1240	1721	2030	372	0.4692
Gypsum	340	341	201	412	139	0.2769
Boron	570	415	382	620	188	0.2602
Zinc	492	538	596	703	-104	0.6110
Weed control	834	616	156	462	679**	0.0045
Plant protection	675	682	999	1292	-324	0.2880
Irrigation	1115	622	1379	1123	-264	0.3302
B. Fixed cost (FC)	24949		26874	2427	-1925***	0.0000
Lease cost of land	24949		26874	2427	-1925***	0.0000
C. Total cost (TC)	52775	6093	58509	11225	-5734**	0.0374

Note: Figures with negative sign in mean difference column indicate the amount saving by CA adopters over non-adopters, while non-negative figures indicate additional amount.
*'***', '**' and '*' indicate significant at 1%, 5% and 10% level.*

Table 36. Profitability differential in mustard cultivation-adopters vs. non-adopters

(Figure in Tk/ha)

Inputs	Adopter (n=11)		Non-adopter (n=35)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
C. Gross return (GR)	75980	6153	62657	9795	13323***	0.0000
Grain yield (t/ha)	1.52	0.13	1.28	0.18	0.24***	0.0000
Sale price (Tk/ton)	47727	2611	46479	3191	1249	0.2056
Income from grain	72568	5380	59620	9416	12949***	0.0000
Value of straw	3412	1388	3037	1102	376	0.4260
B. Cultivation cost						
Fixed cost (FC)	24949		26874	2427	-1925***	0.0000
Variable cost (VC)	27825	6093	31635	9512	-3810	0.1302
Total cost (TC)	52774	6093	58509	11225	-5735**	0.0374
Gross margin (GR-VC)	48155	6605	31021	6824	17134***	0.0000
Net return (GR-TC)	23205	6605	4147	7103	19058***	0.0000
C. Benefit cost ratio						
Over VC	2.73	0.56	1.98	0.49	0.75***	0.0014
Over TC	1.44	0.16	1.07	0.13	0.37***	0.0000

Note: Figures with negative sign in mean difference column indicate the amount saving by CA adopters over non-adopters, while non-negative figures indicate additional amount.
*'***'and '**' indicate significant at 1%, and 5% level.*

3.3.4 Wheat cultivation

Adoption of CA led to input saving in wheat cultivation of adopters over non-adopters by 9.7% in human labour, 31.4% in seed, 8.6% in FYM, around 17% in urea, 12.2% in MoP, and 27.1% in DAP fertilizer. In many operations by human labour, adopters got 100% advantage on land preparation and seed sowing, around 21% in fertilization, and 16% in irrigation. Other operations where adopters had advantage included plant protection and irrigation (Table 37). This illustrates the superiority of crop establishment by VMP over conventional tillage and planting technique.

There was a saving in the total cost of wheat cultivation of more than 6% in the study areas. The adopter farmers incurred 50.4% lower costs for land preparation, 9.2% in human labour, and 33% in wheat seed (Table 38). The table also provides ample evidence that conservation agriculture saved considerable input cost in resources like FYM, fertilizers, plant protection chemicals, and irrigation. However, adopter farmers incurred higher cost on weed control chemicals compared to non-adopters.

The productivity of wheat crop with conservation agriculture was 6.21% higher than conventional tillage in the study areas. Singh et al. (2011) in their study on productivity of wheat in Haryana and Punjab states of India observed that on an average, the productivities of timely sown wheat crop with zero tillage were higher than conventional tillage by 4.62% and 8.33%, respectively. Better grain yield combined with the lower input costs, resulted in a net return of Tk. 21748 per hectare in the case of adopters which was around 76% higher than that of non-adopters in the study areas. These advantages are quite attractive and can serve as incentives to a farmer to switch over to conservation agriculture (Table 39).

Table 37. Input saving in wheat cultivation by CA adopters over non-adopters

(Figure per ha)

Inputs	Adopter (n=67)		Non-adopter (n=102)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
Labour (Man-day)	34.89	10.81	38.64	7.32	-3.75**	0.0129
Land preparation	0.00	0.00	2.37	1.07	-2.37***	0.0000
Seed sowing	0.00	0.00	1.33	0.97	-1.33***	0.0000
Irrigation	2.29	0.82	2.71	1.31	-0.43***	0.0099
Fertilizing	1.43	0.59	1.80	1.07	-0.37***	0.0038
Harvesting	25.44	7.44	26.22	5.41	-0.78	0.4977
Threshing	5.73	8.30	4.20	6.19	1.53	0.2210
Seed (kg)	113.82	8.17	165.91	29.49	-52.09***	0.0000
FYM (kg)	3921	4386	4290	4904	-369.00	0.5540
Fertilizers						
Urea (kg)	158.55	41.06	190.49	66.13	-31.94***	0.0001
TSP (kg)	111.25	38.23	107.52	59.01	3.73	0.6328
MoP (kg)	79.37	20.74	90.40	41.40	-11.03**	0.0221
DAP (kg)	23.01	42.19	31.57	53.85	-8.56	0.2289
Gypsum (kg)	46.56	38.99	29.89	42.81	16.67***	0.0100
Boron (kg)	5.64	3.62	4.11	4.47	1.53**	0.0132
Zinc (kg)	4.44	4.89	2.91	4.51	1.53**	0.0507

Note: Figures with negative sign in mean difference column indicate the amount of input saving by CA adopters over non-adopters, while non-negative figures indicate additional amount of input.
*'***' and '**' indicate significant at 1% and 5% levels.*

Table 38. Input cost saving in wheat cultivation by CA adopters over non-adopters

(Figure in Tk/ha)

Inputs	Adopter (n=67)		Non-adopter (n=102)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
A. Variable cost (VC)	36228	6061	40520	8361	-4292***	0.0001
Land preparation	2446	511	4934	804	-2487***	0.0000
Human labour	8662	2691	9543	1818	-881**	0.0187
Seed	3685	555	5499	1295	-1814***	0.0000
FYM	2858	2925	3070	3448	-212	0.6058
Fertilisers						
Urea	2649	652	3139	1087	-491***	0.0003
TSP	2711	886	2672	1496	39	0.8587
MoP	1259	336	1428	665	-168**	0.0298
DAP	708	1297	970	1687	-262	0.2363
Gypsum	400	350	266	388	134**	0.0204
Boron	775	521	530	592	245***	0.0050
Zinc	535	609	344	561	191**	0.0491
Weed control	1019	748	465	586	554***	0.0000
Plant protection	635	817	751	994	-116	0.5161
Irrigation	2563	1215	3290	1486	-727***	0.0007
Threshing	5323	1390	3619	1147	1704***	0.0000
B. Fixed cost (FC)	22864	2480	22626	2610	238	0.4978
Lease cost of land	22864	2480	22626	2610	238	0.4978
C. Total cost (TC)	59092	6161	63144	6937	-4052***	0.0000

Note: Figures with negative sign in mean difference column indicate the amount saving by CA adopters over non-adopters, while non-negative figures indicate additional amount.
*'***'and '**' indicate significant at 1% and 5% levels.*

Table 39. Profitability differential in wheat cultivation-adopters vs. non-adopters

(Figure in Tk/ha)

Inputs	Adopter (n=11)		Non-adopter (n=35)		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
D. Gross return (GR)	80840	13452	75526	13513	5314**	0.0119
Grain yield (t/ha)	3.59	0.63	3.38	0.68	0.22**	0.0354
Sale price (Tk/ton)	21748	1028	21705	1678	43	0.7929
Income from grain	78041	13481	72821	13330	5220**	0.0130
Value of straw	2799	1034	2705	1194	94	0.6031
B. Cultivation cost						
Fixed cost (FC)	22864	2480	22626	2610	238	0.4978
Variable cost (VC)	36227	6061	40518	8361	-4291***	0.0001
Total cost (TC)	59091	6161	63144	6937	-4053***	0.0000
Gross margin (GR-VC)	44613	12614	35008	10290	9605***	0.0000
Net return (GR-TC)	21748	12468	12382	10488	9366***	0.0000
C. Benefit cost ratio						
Over VC	2.23	0.45	1.86	0.31	0.37***	0.0000
Over TC	1.37	0.22	1.20	0.16	0.17***	0.0000

Note: Figures with negative sign in mean difference column indicate the amount saving by CA adopters over non-adopters, while non-negative figures indicate additional amount.
*'***'and '**' indicate significant at 1% and 5% levels.*

3.3.5 Overall impact on crop yield, variable cost and farm profitability

Propensity score matching method was also used to estimate the impact of CA technologies adoption on the crop yield, variable costs, and farm profitability. A common support region was selected and the balancing property was satisfied for this method. It is stated earlier that CA technology adopters received crop yield higher than that of non-adopters. The non-parametric matching estimates generated through different matching methods revealed that CA technology adopters received average higher yield[4] up to 3.81 t/ha compared to non-adopters in the study areas and these estimates were highly significant at 1% level (Table 40).

Crop production cost was classified into two parts: fixed cost and variable cost. CA technology mainly impacted on tillage operations, seeding, fertilizing and the use of different inputs. Therefore, variable cost is more appropriate to evaluate the CA technology adoption at farm level. However, based on different matching methods, the average variable cost saved by the CA technology adopters ranged from Tk.3439 to Tk.6122 per hectares which were highly significant at 1% level (Table 40).

Based on Kernel and Radius matching methods, the average net income of the CA technology adopting farmers was increased by Tk. 6679 to Tk. 15082 per hectare compared to non-adopters. The Radius estimates of net income were highly significant at 1% level, but the estimates of Karnel and stratification methods were much lower compared to Radius methods which were not significant at all (Table 40).

[4] The average yield, variable cost and net profit were calculated from four crops: maize, wheat, mustard and lentil

Table 40. Impact of CA technology adoption on crop yield, variable cost and net income of selected crop cultivation

Matching method and outcome	No. of treatment (*Adopter =135*)	No. of control (*n = 270*)	Average treatment of treated (ATT)	Std. error	T-value
Impact on crop yield (t/ha)					
Nearest neighbor matching	135	50	3.35***	0.589	5.675
Kernel matching	135	194	3.63***	0.270	13.449
Radius matching					
5%	123	194	3.81***	0.265	14.407
10%	130	194	3.73***	0.285	13.084
Impact on variable cost (Tk/ha)					
Nearest neighbor matching	135	50	-5503***	1432	-3.842
Kernel matching	135	194	-6122***	697	-8.790
Radius matching					
5%	123	194	-3439***	1724	-2.000
10%	130	194	-3440***	511	-6.739
Impact on net profit (Tk/ha)					
Kernel matching	135	194	6979	6524	1.070
Radius matching					
5%	123	194	14140***	3839	3.684
10%	130	194	15082***	5026	3.001

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

3.4 Farmers' Perceptions in Using CA Technologies

The CA adopting farmers in the study areas were asked to point out the advantages of CA technologies that were experienced over the last one or two years back. They mentioned many positive benefits of CA technology during crop production (Table 41). The highest proportion of CA farmers (95.6%) mentioned that they could save labour costs in many operations of crop cultivation. More than 94% farmers opined that CA systems significantly reduced the cost of land preparation and seed sowing since VMP requires single pass to complete planting and seeding operations. Another important observation of the farmers was that adoption of CA technology required less amounts of seed and seed placement was also better (91.1%) compared to conventional cultivation. Many farmers (63.7- 69.6%) opined that CA technologies could successfully reduce the amount of irrigation water and fertilizer. The results of several studies (Singh et al., 2011; Singh et al., 2010; Hossain et al., 2009; Mehla et al., 2000; Gupta et al., 2003) also supported the aforesaid statements of the farmers.

Table 41. Benefits of conservation agriculture as perceived by CA farmers

Advantages	N	% response
1. Require less labour and saving cost of labour	129	95.6
2. Reduced land preparation and seed sowing cost	127	94.1
3. Require less amount of seed/good placement of seed	123	91.1
4. Require comparatively less irrigation	94	69.6
5. Require comparatively less fertilizer	86	63.7
6. Weeding and pesticides application become easy	88	65.2
7. Crop harvests become easy	90	66.7
8. Increase soil fertility	85	63.0
9. Timely seed sowing possible	81	60.0
10. Incidence of low insects and diseases	46	34.1
11. Good yield with lower cost	41	30.4

Many CA farmers told that weeding and pesticides application (65.2%) and crop harvest (66.7%) are become easy due to line sowing of the seeds under strip tillage. The other positive observations of the farmers were increase in soil fertility (63%), possibility of timely seed sowing (60%), low attack of insects and diseases (34.1%), and good yield with lower cost.

The respondent farmers also mentioned some negative sides of CA technologies. More than half of the CA farmers complained that CA machineries especially VMP was not available in the study areas. All types of fertilizers could not be applied together using VMP which was mentioned by 36.3% farmers. Skill operator is very important for operating VMP. But skill operators are scares in the study areas. About 34.1% farmers complained this as a problem.

Table 42. Problems of conservation technologies faced by CA farmers

Disadvantages	N	% responses
1. Non-availability of CA machineries	71	52.6
2. All types of fertilizers can't be applied together	49	36.3
3. VPM operation needs skill operators	46	34.1
4. All soils are not suitable for CA practice	44	32.6
5. Emergence of more weeds	12	8.9
6. Maintenance of crop rotation is a difficult task	3	2.2

Generally, loam and sandy loam soils are suitable for strip planting with VMP. It can't be operated in the clay or other hard types of soils which was opined by 32.6% farmers. Weed management in CA is an important task. The emergence of huge weeds in the CA fields was a crucial problem encountered by about 9% of the CA farmers in the study areas. The other problems faced by a small number of farmers were maintenance of crop rotation is a difficult task (Table 42).

The CA technology practicing farmers were asked to answer whether they increase land area for cultivating crops under CA technology in the next year. In this respect, about 83.7% farmers wanted to increase land area for cultivating crops in line with CA in the next year (Fig. 7). They mentioned many reasons for increasing land for cultivating crops using CA technology. These reasons were mostly similar to the positive observations of the farmers regarding CA technologies (Table 41). Only 16.3% adopting farmers will not increase land area due to some reasons such as non-available of VMP (7.4%), need to shift to cultivate other crops (6.7%) and lack of suitable land (Fig. 8).

Fig 7. Intention of CA farmers towards increasing land under CA

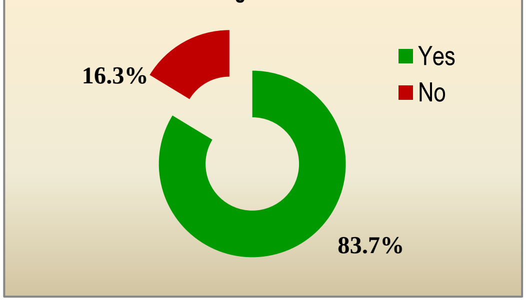
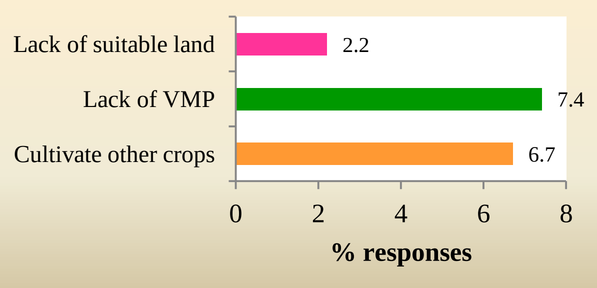


Fig 8. Reasons for not increasing land area for CA



3.5 Future Challenges for CA Adoption

The adoption of such promising technologies is not linear and its adoption depends on many other factors like environmental, socioeconomic, institutional and political circumstances and constraints, rather than technology alone. Future challenges of CA adoption are furnished in Table 43.

The adoptions of CA technologies have to face different challenges in future. The first ranked challenge will be the lack of knowledge and awareness of the farmers about the benefits of CA technologies. On an average, about 93% respondent farmers mentioned this as one of the challenges of its adoption.

The availability of CA machineries is the pre-requisite of successful CA adoption. But for different reasons CA machineries are not widely available in the study areas that will be the main barrier of its wider adoption.

The level of farmers' education in the study areas is not up to the mark. Most of them are illiterate and low educated which is also a challenge for the successful adoption of CA technologies at farm level. Although less educated farmers are more adopters of CA technologies in the study areas at primary or trial stage. When the CA technology spreads widely in the study areas, farmers' education will play crucial role in adopting CA technologies. However, more than 80% respondent farmers raised this issue as a future challenge of its adoption.

Most of the farmers in the study areas are poor and have no ability to purchase 2WT along with CA planter (VMP) for minimum tillage. They have to depend mainly on the local service providers of CA and others machineries for tillage and threshing operations. About 55% farmers stated it as a future challenge for CA adoption.

Table 43. Future challenges of CA adoption in the study areas

Challenges	Adopter *(n=135)*		Non-adopter *(n=270)*		All category *(n=405)*	
	N	%	N	%	N	%
1. Lack of knowledge/awareness toward CA	124	91.9	252	93.3	376	92.8
2. Non-availability of CA machineries	114	84.4	230	85.2	344	84.9
3. Lack of farmers' education and training	117	86.7	210	77.8	327	80.7
4. Farmers' non-ability to purchase CA planter	82	60.7	141	52.2	223	55.1
5. No price subsidy on CA planter	70	51.9	103	38.1	173	42.7
6. Lack of cooperation from supporting organizations	30	22.2	13	4.8	43	10.6

For expanding CA technologies at farm level, the Australian funded CA project provided price support (50 and 25% in year 1 and year 2, respectively) on CA machineries especially on the price of VMP among interested farmers. This price support provision has been taken out after the completion of the project. Such situation has been considered by 43% of the farmers as a challenge for CA adoption in future.

Finally, the successful adoption of CA technologies also depends on many other organizations such as DAE, Bank, Research institutes, machineries manufacturers, etc. Strong collaborative backward and forward linkage program are essential for wider adoption of CA technologies in the study areas which will be also an important challenge toward CA adoption in Bangladesh.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Conservation agriculture is becoming important to many farmers to overcome the problems of labour shortage, increases of cultivation costs, declining agricultural productivity, and farm profitability. The process of CA technology adoption is still on-going in the study areas. Although the level of adoptions of crop residue retention and crop rotations are much higher, the adoption of minimum tillage is too small in the study areas. Traditionally, a good segment of the non-CA farmers retain crop residues in the field and practice suitable crop rotations over the year. Various inherent qualities such as younger age, innovativeness, and extension contact of the farmers have significantly influenced them to adopt CA technologies. The availability of VMP is another crucial factor that influences farmers to adopt the technology to a great extent.

However, limited demonstration, small price support, and commercialization support for the last two years that created some impacts in the study areas to some extent. Conservation tillage using VMP is largely used for different crop establishment. The CA technologies have saved cultivation costs in many operations and reduced the use of resources like seed, irrigation water and fertilizers. The estimates of different PSM methods also reveal that CA technology adoption has significant impact on increasing crop yield, reducing variable costs in many operations, and increasing the net income of the adopters.

Although CA technologies show potentials in many aspects, it faces some challenges towards its higher adoption. The lack of farmer's awareness and non-ability to purchase CA planter, non-availability of CA machineries, no subsidy or price support on CA planter, and lack of cooperation from supporting organizations are the major challenges of its higher adoption.

In the last couple of months ago, Conservation Agriculture Service providers' Association (CASPA) has been formed in order to promote CA technology in the study areas. The influence of CASPA in spreading CA technologies is expected to be strong in the near future.

4.2 Recommendations

Based on the above findings, the following recommendations are crucial for increasing the adoption of these promising and versatile technologies to make agriculture sustainable and farm business profitable.

a) Adequate knowledge and awareness of the farmers are very much important toward the adoption of any new technology. Therefore, the government should provide practical and field oriented training on CA technologies to the enthusiastic farmers. In addition, mass media like radio, TV and daily newspaper can play important role in creating awareness and motivating farmers towards CA technology. In this respect, the government should broadcast the positive impacts of CA technologies using suitable mass media.

b) Demonstration and field day have greater impacts on technology adoption. Therefore, the government should demonstrate CA activities among farmers and conduct field days for wider adoption of CA technologies.

c) Minimum tillage is one of the preconditions of conservation agriculture. Hence, the availability of minimum tillage planters at farm level is essential since it reduces input use, increases crop productivity and farm profitability. The state authority with the help of BARI and DAE should make minimum tillage planters (e.g. VMP, BARI inclined plate planter, BARI zero tillage planter, BARI bed planter, BARI strip tillage planter) available to the farmers through providing soft loan to the manufacturers and interested farmers.

d) Subsidized price can also play important role in spreading out minimum tillage planters among farmers. Government may provide subsidy on minimum tillage planters through nationalized Bank, DAE, and Conservation Agriculture Service Providers' Association (CASPA). Formation of cohesive group of farmers may play important role in this regards.

e) Monitoring is important to keep farmers' interest toward new technology adoption and its continuous use. For instance, DAE personnel and CASPA are working hard in spreading CA in Durgapur, Rajshahi area after completion of the project. Extension personnel involved in technology dissemination generally do not come to the farmer after the completion of the project. Therefore, the government should give emphasis on developing effective monitoring mechanism for CA technology disseminators.

f) Successful adoption of a new technology also depends on many other organizations. Therefore, government should make good linkage among different organizations such as DAE, Bank, Research institutes, machineries manufacturers etc. for higher adoption of CA technologies in Bangladesh.

g) Access to institutional credit of the interested farmers and service providers is low in the study areas. Smallholder farmers should be given hand-on training on operating CA machineries and provide institutional credit without collateral. In this regard, the system of providing credit by BMDA[5] to the interested households for purchasing minimum tillage planter may be followed.

h) Private sector and development partners (NGOs) should come forward to promote CA technologies at farm level. Government should facilitate private sector and development partners to take promotional activities of CA at farm level.

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[5] Barind Multipurpose Development Authority (BMDA) first influences enthusiastic farmers to form a cohesive group of 8-10 persons and recommend the group to National Bank for disbursing required credit to purchase minimum tillage planter along with 2-WT (power tiller). National Bank then provides credit facility to the recommended household (husband and wife jointly) receiving group guarantee as collateral.

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Appendix Table

Table 1. Cropping patterns practiced by the CA and non-CA farmers in the study areas

1. Mustard-Boro-T.Aman	27. Wheat-Mungbean-T.Aman
2. Mustard-Fallow-T.Aman	28. Onion-Jute-T.Aman
3. Mustard-Jute-T. Aman	29. Onion-Vegetables-Vegetables
4. Mustard-Maize-T. Aman	30. Onion-Maize-T.Aman
5. Mustard-Sesame-Fallow	31. Onion-Jute-Fallow
6. Lentil-Boro-T.Aman	32. Onion-Boro-T. Aman
7. Lentil-Maize-T.Aman	33. Potato-Maize-T.Aman
8. Lentil-Vegetables-Vegetables	34. Potato-Boro-T.Aman
9. Lentil-Jute-T.Aman	35. Potato-Brinjal-T.Aman
10. Lentil-Fallow-Aman	36. Potato-Vegetables-Vegetables
11. Lentil-Mungbean-T.Aman	37. Potato-Jute-T. Aman
12. Lentil-Jute-Fallow	38. Potato-Vegetables-Vegetables
13. Lentil-Fallow-Blackgram	39. Chickpea-Fallow-T.Aman
14. Lentil-Cucumber-T.Aman	40. Chickpea-Boro-T.Aman
15. Lentil-Jute-Vegetables	41. Tomato-Maize-T.Aman
16. Lentil-Maize-Fallow	42. Tomato-Fallow-T.Aman
17. Lentil-Sesame-T.Aman	43. Tomato-Boro-T.Aman
18. Wheat-Papaya-Papaya	44. Fallow-Boro-T.Aman
19. Wheat-Boro-T.Aman	45. Fallow-Mungbean-T.Aman
20. Wheat-Vegetables-Vegetables	46. Fallow-Maize-T. Aman
21. Wheat-Blackgram-T.Aman	47. Fallow-Boro-Fallow
22. Wheat-Chilli-Chilli	48. Maize-Fallow-T.Aman
23. Wheat-Jute-T.Aman	49. Maize-Boro-T.Aman
24. Wheat-Sesame-T.Aman	50. Chilli-Chilli-T.Aman
25. Wheat-Maize-T.Aman	51. Cucumber-Boro-T.Aman
26. Wheat-Fallow-T.Aman	52. Brinjal-Jute-T. Aman

Table 2. Percent of inputs saved due to adopt CA technology

(Figure in %)

Inputs	Wheat	Maize	Mustard	Lentil
Human labour	-9.7	-34.2	-0.34	-5.2
Seed	-31.4	-7.7	-20.9	-15.3
Fertilizer	-6.2	+23.9	-2.4	+23.1
Pesticides	-15.5	-30.6	-32.4	+12.2
Herbicides	+119	+295	+435	+454

Note: - and + sign indicate input save and use more inputs in crop production

Table 3. Impact of CA technology adoption on crop productivity (t/ha)

Crop	Adopter	Non-adopter	Mean difference	% higher/lower over control
Lentil	1.68	1.31	0.37***	28.24
Maize	9.16	9.61	-0.45*	-4.91
Mustard	1.52	1.28	0.24***	18.75
Wheat	3.59	3.38	0.21**	6.21

Note: ***, **, and * indicate significant at 1%, 5% and 10% level

Table 4. Percent change in total cost and net profit due to CA technology adoption

(Figure in %)

Inputs	Wheat	Maize	Mustard	Lentil
Total cost	-6.4	-9.3	-9.8	+4.7
Net profit	+75.6	+54.7	+459.6	+47.3

Note: - and + sign indicate cost save and received higher return over control in crop production

Table 5. Summary statistics of variables included in the models

Explanatory variable	N	Mean	Std. Dev.	Minimum	Maximum
A. Adopter					
Age (year)	135	37.48	13.31	17	70
Education (year of schooling)	135	8.26	4.35	0	15
Household size (No./HH)	135	5.45	1.97	2	12
LnFarm size (decimal)	135	5.26	0.70	3.50	7.82
Societal membership (wt. score)	135	0.95	1.22	0	6
Innovativeness (wt. score)	135	3.07	2.47	0	10
Extension contract (wt. score)	135	13.30	4.88	6	36
Availability of VMP (score)	135	1.69	0.51	1	3
Training (No./life time)	135	2.18	3.96	0	25
Cosmopolitness (Score)	135	6.72	2.17	2	12
B. Non-adopter					
Age (year)	270	41.94	14.66	16	85
Education (year of schooling)	270	7.35	4.90	0	16
Household size (No./HH)	270	5.00	1.98	1	16
LnFarm size (decimal)	270	5.13	0.78	3.22	7.82
Societal membership (wt. score)	270	0.48	1.04	0	8
Innovativeness (wt. score)	270	1.43	1.91	0	8
Extension contract (wt. score)	270	10.73	4.16	1	22
Availability of VMP (score)	270	0.82	0.59	0	2
Training (No./life time)	270	1.26	2.13	0	15
Cosmopolitness (Score)	270	5.84	2.20	1	10

Table 6. Correlation matrix of variables included in the model

	Age	Educa	HHsize	Training	Lnland	VMP avail	Member	Innovat	Cosmo politnes	Exten.
Age	1.00									
Educa	-0.44	1.00								
HHsize	0.10	-0.07	1.00							
Training	0.05	0.19	0.10	1.00						
Lnland	0.13	0.17	0.24	0.10	1.00					
VMPavail	-0.11	0.10	0.08	0.12	0.10	1.00				
Member	-0.02	0.24	0.10	0.29	0.07	0.13	1.00			
Innovat	-0.08	0.20	-0.03	0.20	0.07	0.39	0.24	1.00		
Cosmopo	-0.15	0.29	0.05	0.12	0.21	0.24	0.20	0.29	1.00	
Exten.	-0.11	0.47	0.05	0.33	0.26	0.19	0.38	0.30	0.49	1.00

Table 7. Breusch-Pagan/ Cook-Weisberg test for heteroskedasticity in linear model

Particular	Values	H_0	Remarks
Fitted values for yield		Constant variance	No heteroskedasticity problem in the model
Chi^2 (1)	110.98		
Prob > Chi^2	0.0000		
Fitted values for VC		Constant variance	No heteroskedasticity problem in the model
Chi^2 (1)	14.66		
Prob > Chi^2	0.0001		
Fitted values for net income		Constant variance	No heteroskedasticity problem in the model
Chi^2 (1)	27.86		
Prob > Chi^2	0.0000		

STATA OUTPUT OF PSM FOR CROP YIELD, VARIABLE COST AND NET INCOME

Table 8. Algorithm to estimate the propensity score, the treatment is CA technology adoption

Dependent variable	Frequency (N)	Percent	Cumulative
0	270	66.67	66.67
1	135	33.33	100.00
Total	405	100	

Note: CA technology adopter = 1, Non-adopter = 0

Table 9. Description of the estimated propensity score in region of common support

	Estimated propensity score			
	Percentiles	**Smallest**		
1%	0.0409702	0.0357614	Observations	329
5%	0.0660177	0.0373635	Sum of weight	329
10%	0.0792719	0.0397078	Mean	0.4087666
25%	0.1371539	0.0409702	Std. Deviation	0.3087577
50%	0.2688874	--		
		Largest	Variance	0.0953313
75%	0.7201831	0.9951965	Skewness	0.4861939
90%	0.8770218	0.9966191	Kurtosis	1.6717330
95%	0.9118600	0.9981189		
99%	0.9951965	0.9989296		

<u>Test of Balancing Property of the Propensity Score</u>

Step 1: Identification of the optimal number of blocks

The final number of blocks is 6.

The number of blocks ensures that the mean propensity score is not different for treated and controls in each blocks.

Step 2: Test of balancing property of the propensity score

The balancing property is satisfied

This table shows the inferior bound, the number of treated and the number of controls for each block.

Table 10. Test of balancing property of the propensity score

Inferior of block of 'pscore'	Participation		Total
	Non-adopter (0)	Adopter (1)	
0.0357614	49	2	51
0.1	63	15	78
0.2	41	22	63
0.4	19	7	26
0.6	18	36	54
0.8	4	53	57
Total	**194**	**135**	**329**

Note: The common support option has been selected.