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Factors Affecting Conservation Agriculture Technologies at Farm Level in Bangladesh

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ABSTRACT

Conservation agriculture (CA) is a win-win approach that reduces operational costs, including machinery, labour, and fuel, while increasing yields, profit and better utilization of natural resources. Data and information on farm level CA technology adoption are scarce in Bangladesh. Therefore, the study was conducted at three *Upazilas* of Rajshahi and Thakurgaon districts to assess adoption and farmers perceptions on CA technology, and to determine the factors of CA technology adoption at farm level in 2017. A total of 405 farmers taking 135 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%) were much higher compared to minimum tillage (14.9%). Residue retention (68.9%) and suitable crop rotations (34.4%) were also practiced by the non-adopters. The age, innovativeness, and extension contact of the farmers and availability of VMP had significant positive influence on the adoption of CA technologies. The major problems of adoption were non-availability of minimum tillage planter, lack of knowledge and awareness of the farmer, and no/little subsidy provision on planter. Increasing the availability of VMP, providing training on CA methods, and providing subsidy on planter are important to increase CA technology adoption at farm level.

1. Introduction

Agriculture in Bangladesh is well advanced in adopting farm mechanization particularly in land preparation, irrigation, and threshing. However, the growing threat to crop production is the shortage of labour which impacts especially on crop establishment, weed control, and harvesting [19]. 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 [29]. 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

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and through using natural resources that have minimal adverse impacts on soil and environment [11]. In this context, conservation agriculture (CA) and mechanization are becoming increasingly important to overcome the problems of declining agricultural productivity in Bangladesh.

CA 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 principles (IIRR and ACT, 2005). The principles are (a) minimal soil disturbance; (b) crop residue retention; and (c) suitable crop rotations [41]. 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 [22]. Minimum tillage practice increases the levels of soil organic matter [6,15], water retention capacity [4,25], irrigation requirements[8,21], increases crop yield and decreases production costs [32,12], and minimized turn-around time between the crops [16]. Crop residue retention on the top of the soil with any number of tillage systems plays a crucial role in improving agronomic yield and environmental quality [1,31]. 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 [33,39]. Long-term crop residue incorporation builds SOM level and N reserves, and increases the availability of macro- and micro-nutrients [34]. Suitable crop rotation has many agronomic, economic and environmental benefits over continuous cropping [2]. Crop rotation can help maximize crop yield potential and profitability over time [26], control weeds [7,20], break disease cycles, limit insect and other pest infestations [37], increase soil organic matter, and provide an alternative source of nitrogen [23,28]. Besides grain crops, the inclusion of legume in a cropping pattern can maintain soil fertility and sustain crop productivity to a great extent [9].

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. CA is a win-win approach that reduces operational costs, including machinery, labour, and fuel, while increasing yields and better utilization of natural resources [30]. 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 [2].

Realizing the importance of CA in Bangladesh, the scientists of Murdoch University, Australia with the support of Australian Government and in collaboration with Bangladesh Agricultural University, BARC, BARI, BRRI, 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 ACIAR since April 2012 to March 2017. The project has developed and accelerated the adoption of CA technology for selected soils, crops and cropping systems in different areas of Bangladesh, especially in the rainfed areas and those with supplementary irrigation. Respondent farmers have received benefits from cost saving crop production technologies and sustainable resource management through adopting CA technologies. They have established and grown different crops such as wheat, maize, pulses, oilseeds, jute, and rice successfully through CA technology [3,14]. Therefore, an attempt was made to assess the adoption of CA technology at farm level for providing feedback of the project to researchers and policy makers who can formulate appropriate policy guidelines to disseminate CA technologies to other new areas of the country.

Specific Objectives

(1) To assess the adoption status of CA technologies at farm level.

(2) To determine the factors influencing CA technology adoption at farm level.

(3) To assess the perceptions of farmers about CA technology adoption at farm level.

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, Thakurgaon, Rajshahi and Mymensingh. Considering project resources, logistic support and CA technology adoption, three *Upazilas* namely Durgapur and Godagari *Upazilas* of Rajshahi district and *Sadar Upazila* of Thakurgaon district were purposively selected for the study.

2.2 Sampling Design and Data Collection

The households were selected considering the level of adoption of CA technologies. At first, a complete list of farmers adopted CA technologies (i.e. minimal soil disturbance, crop residue retention, and suitable crop rotations) was prepared with the help of personnel from DAE and CA project. Then, a total of 135 CA farmers taking 45 farmers from each *Upazila* were selected randomly for

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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. Data and information were gathered from selected farmers using a pre-tested interview schedule. Data were collected during January-February, 2017.

2.3 Analytical Techniques

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 Logit model was used to identify factors of CA technology adoption at farm level.

According to Gujarati [10], the Logit model guarantees that the estimated probabilities lie in the 0-1 range and that they are not linearly related to the explanatory variables. In addition, it is easier and more convenient to compute than the Probit model. Since the dependent variable is dichotomous, OLS cannot be used. MLE method was followed to run the Logit model using STATA software (Version 12). The specification of the model was as follows:

$$\text{Logit}\,\{P(Y=1)\} = \log\{P/(1-P)\} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots + \beta_K X_K$$

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 Logit model was as follows:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8$$

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 = Ln-Farm 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.

3. Results and Discussion

3.1 Status of CA Technologies Adoption

Conservation agriculture is a new concept in Bangladesh although extensively practiced in many countries of the world. Farmers in Bangladesh generally practice one or two CA principles, but not three principles together. However, considerable efforts were made to popularize CA technology among interested farmers in different areas of Bangladesh. The adoption status of CA principles is discussed below.

Adoption of minimum tillage operations: In the study areas, Versatile Multi-crop Planter (VMP) is being promoted for crop establishment in minimum soil disturbance. Majority of the farmers belonged to adopter and non-adopter groups used full tillage operation by 2-WT (power tiller) for land preparation and 100% CA farmers used VMP for minimum soil disturbed crop establishment in single pass operation (Table 1). A study found that 41-43% less irrigation water was used by crops established by VMP planting as compared to a traditional tillage system [18]. The uses of Power Tiller Operated Seeder (PTOS) and country plough are rare in the study areas.

Table 1. Status of tillage/planting operations in the study areas

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

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 (Table 2). Such response from non-adopters might be due to lack of knowledge and mindset on minimum soil disturbance. Both categories of farmers who responded in favor of minimum soil disturbing technologies mentioned various drawbacks of intensive tillage. Table 2 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

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of fertilizers and irrigation (Table 2).

Table 2. 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
Disadvantages 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.

Adoption status of crop residue retention: There are trade-offs in the role of residues in (1) boosting grain yields, (2) providing a resource for livestock feed and cooking, and (3) providing ground cover to reduce erosion potential [24]. The retention of crop residues can substantially reduce the amount of inorganic fertilizers use which brings both environmental and economic benefits to the farmers [38]. Knowingly or unknowingly the benefits of residue retention, many farmers in the study areas are retaining crop residues in their fields over the years. Both adopting and non-adopting farmers generally retain crop residues in the field after harvesting of rice (*Boro &Aman*), wheat, and maize to a varied extent. Table 3 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.

Table 3. Average height 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

Respondent farmers 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 4).

Table 4. Reasons for retaining crop residues in the field

Reasons for retaining crop residue	Adopter (*n=135*)		Non-adopter (*n=270*)	
	Frequency	%	Frequency	%
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.

Adoption status of crop rotations: A crop rotation is the practice of growing a series of different types of crops in the same area over a sequence of seasons. 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 [42]. 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 [1].

For many reasons, both CA and non-CA farmers in the study areas have been practicing crop rotations over the years, because they know well that monoculture reduces crop productivity. Some farmers practiced crop rotations for maintaining soil fertility. Table 5 shows that half of the CA farmers and 34.4% of the non-CA farmers adopted crop rotations over the years. Surprisingly, about 50% CA farmers did not practice crop rotations in the past. Currently, they are adopting suitable crop rotation since most CA farmers are passing 1st year and 2nd year through prac-

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ticing CA. However, they have intention to follow suitable crop rotations in future.

Table 5. 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. 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 6 & 7). The other important patterns were reported as *Wheat-Maize-T.Aman*; *Wheat-Fallow-T.Aman* and *Wheat-Mungbean-T.Aman*. The cultivation of pulse (lentil) is highly remunerative to the farmers. Therefore, 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 [9]. Some sampled farmers also thought that suitable crop rotations can reduce the incidence of insects and diseases.

Table 6. 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

Notes: *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 7. 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

Notes: *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

Overall Rate of adoption of CA technologies: During the period (2012-2015) many farmers observed the benefits of CA technologies and adopted them gradually. This adoption process is still on-going in the study areas. However, the survey results showed that on an average 20.3% of farmers from Rajshahi and 10.1% of farmer from Thakurgaon 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 [13]. 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 8).

Table 8. Rate of adoption of conservation agriculture technologies

Particular	Rajshahi		Thakurgaon		Both area	
	n	% adoption	n	% adoption	n	% adoption
Total farm households	316	--	348	--	664	--
Strip planting with VMP users	64	20.3	35	10.1	99	14.9
Bed planter users	15	4.7	--	--	9	2.3
Zero tillage users	9	2.8	--	--	9	1.4
Crop residue retention users	189	59.8	256	73.6	445	67.0
Crop rotation practicing farmers	112	35.4	146	42.0	258	38.9

3.2 Factors Influencing the Adoption of CA Technologies

The adoption of CA technologies was likely to be influenced by different socio-economic factors such as age, education, availability of VMP, extension contract, and innovativeness. The marginal effects of the variables determining adoption of CA technologies are presented in Table 9. 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. Marginal coefficient indicates that if the age of farmer decreases by 100%, the probability of adopting CA technologies would be increased by 0.45%.

Usually, education has positive influence on new technology adoption [27,40]. In this study, education had significant negative impact on the adoption of CA technologies

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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 2.06%.

Table 9. Marginal effect of the variables determining adoption of CA technologies among respondent farmers

Explanatory variable	Dy/dx	SE	z-statistic	Probability
Age (year)	-0.0045**	0.0021	-2.19	0.028
Education (year of schooling)	-0.0206***	0.0071	-2.87	0.004
Household size (No./HH)	0.0178	0.0124	1.43	0.152
LnFarm size (decimal)	0.0222	0.0366	0.60	0.545
Availability of VMP (score) (Scale,0-4; 0= not available, 4= plenty)	0.4341***	0.0478	8.94	0.000
Societal membership (wt. score) (Scale,0-4; 0= No membership, 4= Executive member)	0.0351	0.0249	1.42	0.156
Innovativeness (wt. score) (Scale,0-2; 0= no involvement, 2= involved)	0.0311***	0.0115	2.69	0.007
Extension contract (wt. score) (Scale,0-4; 0= no contact, 4= regular contact)	0.0240***	0.0072	3.29	0.001

Note: Dependent variable = CA technology adoption (Adopter = 1, Non-adopter = 0)

No. of observation = 403; LR chi-square (8) = 202.61; Log likelihood = -154.27; Pseudo R^2 = 0.3964

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

Higher score value represents the higher probability of CA technology adoption

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 43.41%, if the availability of VMP is increased by 100%.

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. Logit 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 2.4%, if the extension contact is increased by 100%.

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 3.11% (Table 9).

3.3 Perception of Farmers about CA Technology Adoption

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 10). 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 [14,35-36] also supported the statement of the farmers. 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.

Table 10. Benefits of CA technology adoption as perceived by CA farmers

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

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. 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. The other problems faced by a small number of farmers were maintenance of crop rotation is a difficult task and minimum tillage produces less yields (Table 11). However, these statements were appeared might be due to lack of their mindset towards conservation agriculture.

Table 11. Disadvantages of CA technology adoption faced by CA farmers

Disadvantages	Frequency	% 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
7. Minimum tillage produces less yield	2	1.5

3.4 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 12.

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. 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. 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.

Table 12. 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

4. Conclusions and Recommendations

4.1 Conclusions

CA 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

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adoptions of crop residue retention and crop rotations are much higher, the adoption of minimum tillage is too small. 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 (minimum tillage) to a great extent. 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.

4.2 Recommendations

The following recommendations are crucial for increasing the adoption of these promising and versatile technologies to make agriculture sustainable and farm business profitable.

(1) The government should provide practical and field oriented training on CA technologies to the enthusiastic farmers. In this respect, the government should broadcast the positive impacts of CA technologies using suitable mass media.

(2) 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.

(3) The government should make minimum tillage planters available to the farmers through providing soft loan to the manufacturers and interested farmers. Subsidized price can also play important role in spreading out minimum tillage planters among farmers.

(4) 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.

(5) The government should make good cooperation among different organizations such as DAE, Bank, Research institutes, machineries manufacturers etc. for higher adoption of CA technologies in Bangladesh.

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