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Factors Influencing Farmers' Knowledge, Capacity, and Practice of Conservation Agriculture in Bangladesh

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Abstract

Conservation Agriculture (CA) is an alternative to the conventional farming system, which is considered a way of achieving climate-smart agriculture. Despite various CA support programs and promotional activities in Bangladesh, a major portion of CA farmers are reluctant to continue CA farming. This research aimed to reveal the extent and difficulties of continuing the practice and the gap between farmers' knowledge, ability, and performance. To collect data, we conducted a cross-sectional survey of 201 CA-adopting farmers from northern districts, namely Rajshahi, Rangpur, and Dinajpur. Results show that, among all components of CA practices in the area, most of the farmers regularly practice minimum tillage. The results also indicate that average income, access to and availability of machinery, and the knowledge gap are all commonly significant and have a big effect on the three dependent variables: the can-do gap, the know-can gap, and the know gap. The evidence indicates that reducing these gaps requires subsidies for resource-poor farmers and easy access to the machinery needed for CA practice. Public or private investments, or a combination of both, can effectively reduce these gaps.

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Keywords: Conservation agriculture, Three gap model, Extent, Difficulties, Bangladesh

Introduction

This article deals with the extent of Conservation Agriculture (CA) practice among the farmers in Bangladesh and the difficulties they face, which influence the adoption of CA in the wider context. Like many other Asian countries, Bangladesh has low-input cropping systems dominated by cereal monoculture and rigorous tillage, which helps grow more diseases, weeds, and pests, resulting in decreased profit margins for the farmers. This very agricultural model, which is largely based on soil tillage, is not sustainable and is typically accompanied by adverse impacts on natural resources and the biodiversity of the soil. Continuing this traditional system will jeopardize the ecology of farming since this agricultural practice acts as a major driver of biodiversity loss and contributes to speeding up the loss of soil by enhancing the mineralization of organic matter and erosion rates (Corsi and Muminjanov 2019). In addition, the ever-growing population of Bangladesh demands greater productivity of food and the agricultural system as a whole (Gerland et al. 2014; GOB 2012; Hoque 2024). This concern remains at the heart of this discussion around food security in the age of increasing climate change threats in Bangladesh.

However, the concern is not just the quantity of food or yield, but also the quality of the food grains, products, land, and the environment around us. Continuous and persistent use of pesticides and chemically induced fertilizers without using organic materials and processes results in soil degradation and advances the decline of soil productivity and fertility (Kafiluddin and Islam 2008). In this critical time, the country requires a sustainable, smart, and eco-friendly farming system to provide food security for the growing population and increased income to improve farmers' livelihoods and to minimize the negative impacts on our environment. In this context, CA is an important alternative in overcoming these problems while improving production efficiency and soil health. Along with other climate-smart agricultural innovations, CA can increase yields, incomes, and farmers' welfare (Makate et. al., 2019). This practice is considered to advance a system avoiding or minimizing soil mechanical disturbance coupled with soil cover and crop diversification, which is a supportable agro-ecological method to resource-conserving agricultural manufacture (Corsi and Muminjanov 2019). As previously discussed, a complete adoption of CA is a contested issue. Various organizations and approaches have advanced the same idea with different conceptualizations. In this study, the basic principles theorized and propagated by FAO were considered. They are – (i) minimum soil disturbance (zero tillage

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or reduced tillage), (ii) permanent soil cover in at least 30% of land in the form of crop residue or live mulches, and (iii) intercropping or crop rotation involving at least 3 different crop species (FAO 2019). The extent of the practice can be measured by these principles.

CA is a win-win approach that reduces operational costs, including machinery, labor, and fuel, while increasing yields and better utilizing natural resources (Roy et al. 2009; Hoque 2020). Considering the extent and difficulties of CA, Kassam et al. (2019) reported CA was being practiced on 106 million hectares of land around the world in 2008 and 180 million hectares in 2016, which is an increase of 68.5% in eight years. Perego et al. (2019) compared CA and CF and found that CA is more profitable and often less difficult than CF, and biological fertility increases for CA farming. However, the benefits attached to CA have been explored and examined in various studies (Abdulai and Abdulai 2017; Ghaley et al. 2018; Kaweesa et al. 2020; Pannell, Llewellyn, and Corbeels 2014; Pradhan et al. 2018; Shahzad et al. 2017). Only a few countries (i.e., USA, Argentina, Brazil, Australia and Canada) share 90% of CA land area, whereas South Asian countries have only around 2.77% of that land (5 million hectares) under this farming system (Biswas, Prativa, and Chaudhari 2017). This indicates that the extent and difficulties of CA practice are context-specific. Promotional strategies depending on farmers' knowledge of CA may unintentionally encourage the adoption of "no-till" alone, which has previously been shown to have negative effects on crop yields (Pittelkow et al. 2015). While discussing the real practice of CA, it was noted that conservation tillage is not conservation agriculture (Reicosky 2015). Therefore, limited and partial adoption of CA is related to socio-economic and agro-ecological constraints (Arslan et al. 2014; Giller et al. 2015). Giller et al. (2015) reviewed pertinent literature related to CA in developing countries and suggested that three components of CA adoption should be flexible based on the local context and farmers' socio-economic characteristics.

Despite having a great deal of potential, the adoption of CA is Bangladesh remains limited (Uddin et al., 2016; Hossain et al., 2015). This limitation is not just reflected in the number of farmers adopting this practice, but also in the area of land and the adoption of the principles. As Pannell et al. (2014) argue, the rate of adoption may vary due to the costs and risks of CA, and also on its benefits, availability of resources (human, land, or financial), or the farmers' risk preferences. Hossain (2017) explored several factors that limit CA in Bangladesh, including farmers' beliefs, peer pressure, lack of private sector investment, perceived difficulties, and environmental and health concerns.

In this backdrop, the aim of the study was to illustrate the extent of CA practices among farmers and the difficulties in continuing conservation

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farming practices. Pagliacci et al. (2020), Rohila et al. (2018), and Tsige et al. (2020) identified the concept of "difficulties" in adopting climate-smart agricultural practices. Previous studies discussed the problems of the continuation of CA practices, which provided the basis of this survey (Akter et al. 2021; Dhar, Islam, and Ahmed 2017; Uddin and Dhar 2018; Dhar et al. 2018). However, studies related to the extent of CA farming practices and difficulties in continuing were not found. This study fills the gap and adds new knowledge in the context of the continuation of conservation agriculture.

Materials and Methods

Data Collection

The data for this study were collected in two phases among farmers from three districts located in the northern part of Bangladesh. The three purposively selected districts were Rajshahi, Rangpur, and Dinajpur. The reasons to include these three geographical areas are (a) agriculture was the primary livelihood of inhabitants (Tama et al. 2018), (b) these areas were reported to be hit by adverse climatic effects, including drought, lack of groundwater and flash floods (Islam et al. 2014; Hoque 2023; Tama et al. 2023), and (c) several international projects were carried out with a view to promoting climate-smart agricultural practices among the farmers in these areas (Tama and Hoque 2025). Farmers were selected using a multi-stage sampling technique. At the first stage, the authors carried out a purposive literature review to identify which geographical areas would be suited for data collection. This prompted the selection of the abovementioned three districts. At the second stage, six sub-districts were identified where many farmers adopted and practiced CA. At the third stage, a list of CA farmers was collected from the local agricultural research and extension offices. Finally, 201 CA farmers were selected for this survey. Although the number of female farmers was relatively small, female representation was ensured. While the survey was carried out in 2019-20, several focus group discussions (FGDs) followed.

Designing the Questionnaire

A structured questionnaire, which was divided into two major sections, was prepared to obtain the respondents' information. The first section collected information related to the socio-economic characteristics of respondents, including age, sex, formal education levels, farm size, cropping patterns, and physical assets. The second section encompassed the information regarding conservation agriculture, problems faced by CA farmers, and the extent of CA farming done by them.

Before finalizing the survey questionnaire, a series of activities, such as literature review, group discussions among agricultural experts and

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researchers, pilot studies, etc., were conducted. Students from Bangladesh Agricultural University were hired and trained for data collection. During the data collection period, data enumerators collected most of the data in the local unit and then converted it to the standard and closely scrutinized it afterwards.

Analytical Technique

The study used descriptive statistics (average, maximum, minimum, percentage, etc.) and mathematical techniques (i.e., problem confrontation index) to achieve the objective of the study. The extent of CA farming practice was evaluated based on seven (7) components of this farming. Poddar et al. (2017) identified eight (8) components of CA practiced by Bangladeshi farmers. But in the selected areas, this study identified the following seven (7) components of CA that are commonly practiced by farmers. The components are zero tillage, minimum tillage, leaving crop residues in the field, following crop rotation, permanent soil coverage, applying green manure, and applying vermicompost. Farmers' opinions for each component were measured using a 4-point rating scale. This analytical method was previously used by Poddar et al. (2017) and Roy et al. (2015). Weights were assigned to these responses as 3, 2, 1, and 0, where 3 stood for regularly, 2 for occasionally, 1 for rarely, and 0 for not at all, respectively. The extent of CA practice was evaluated through descriptive statistics (e.g., average, number, percentage).

The pathways of translating knowledge to practice are always critical for any adoption-related studies and to understand the extent of practice. In the case of the adoption of CA in Bangladesh, correct assessment requires - (1) components of CA farming, (2) farmers' knowledge of these components, (3) farmers' ability or skills to correctly follow the components, and (4) farmers' application of this knowledge and skills in practice.

Ibnat et al. (2019) proposed the Three-Gap model starts with three measures of performance - performance, capacity, and knowledge - and three gaps: the gap between what a farmer should know (know gap) and what she or he should be doing (in relation to CA practice) and what she or he has the knowledge to do (the know-gap); the gap between what the farmers have the knowledge to do and their capacity to perform (the know-can gap); and the gap between what they have the capacity to do and what they do (the can-do gap). The three-gap model of the study is presented in Figure 1.

Farmers' knowledge was measured against the three components of CA farming. Their capacity was evaluated based on their capabilities to engage themselves in actual CA practice and whether the required machinery was available. For instance, if a farmer knows CA requires a power tiller-operated zero-tillage seeder, and that machine is unavailable or access to it cannot be obtained, capacity will be lower than knowledge. The performance was

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measured with what farmers' actual behavior was (their extent of practice of CA).

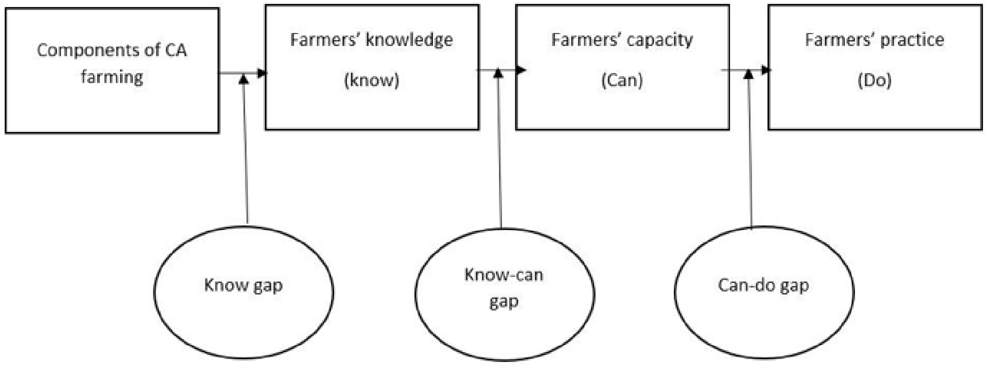

Figure 1: Pathways to farmers' knowledge to practice

The pilot survey was carried out among 30 farmers (who were not included in the final sample). Later, nine FGDs were conducted to explore the constraints. This pilot study was motivated by the secondary sources that identified some of the difficulties. The difficulties were recorded as opinion statements, which could later be used as part of the Problem Confrontation Index (PCI) analysis. This served to understand what interventions can be employed to target, influence, and alter those difficulties.

The problem confrontation index (PCI) score of the difficulties faced by CA-adopting farmers was computed and ranked according to the extent of difficulties faced by the farmers. Each farmer was asked to indicate the extent of difficulty caused by each of the problems by checking any of the four responses- 'High, 'Medium, 'Low and 'not at all', and weights were assigned to these responses- 3, 2, 1 and 0, respectively. Thus, the possible range of the problem confrontation score for each problem was from 0 to 3 and a possible range of the overall problem confrontation score for 12 difficulties ranged from 0 to 36. In this case, 0 indicated there was no problem and 36 indicated that the problem was very high. A problem confrontation index (PCI) for each selected problem was computed by using the following formula:

$$PCI = (Phigh \times 3) + (Pmedium \times 2) + (Plow \times 1) + (Pnot\ at\ all \times 0)$$

Where, Phigh = Number of responses indicating the problem occurred frequently. Pmedium = Number of responses indicating the problem occurred occasionally; Plow = Number of responses indicating the problem occurred rarely; and Pnotatall = Number of responses indicating no problem at all. Problem confrontation index (PCI) for any of the selected problems could range from 0 to 603 for CA farmers, where 0 indicated that the problem was

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not faced at all by the farmers, 603 indicated that the problem was very high and frequently faced by the farmers. Finally, the required intervention matrix was provided by dividing the policy actions into three categories (policy intervention required, research required, and extension service required) for expanding conservation agriculture, which will be synchronized for policy options.

Results and Discussions

The study investigated farmers' constraints regarding the continuation of this farming practice and evaluated the strengths, weaknesses, opportunities, and threats of CA practice. Based on the findings, this study suggests a set of policy actions in the form of a recommendation matrix.

Extent of CA Practice

The summary results of practicing the components of CA are presented in Table 1. Results indicate that farmers in the study areas mainly practice minimum tillage (strip, reduced, and ridge). This minimum tillage requires specialized machinery (e.g., a power tiller-operated seeder, a power tiller-operated bed planter, a power tiller-operated strip tillage seeder, or a power tiller-operated zero tillage seeder). The following components are applying vermicompost, leaving crop residue, following crop rotation, maintaining permanent organic soil coverage, and applying green manure. CF practice requires more machinery, labor, cost, and time. On the other hand, zero tillage and minimum tillage require less input, like labor for plowing, and also lower costs since the need for machinery is lower, and also less time. This might be influencing the farmers more to use different components of conservation agriculture practices, especially minimum tillage. Several promotional strategies should be undertaken to diffuse the CA farming practice among the farmers. Findlater et al. (2019) focused on South Africa and found that there exists a miscommunication between farmers and local experts, which resulted in an inappropriate adoption of CA, which may hinderthe actual benefits of this farming practice.

The possible score for the extent of practicing CA components could range from 0 to 21. The observed practice score ranged from 5 to 21. The farmers were classified into three (3) categories according to the practice of components of CA, which is presented in Table 2. Findings indicate that the majority (79.10 percent) of the farmers had medium practice in CA components. This finding is supported by (Poddar, Uddin, and Dev 2017). So, the farmers in the study area practice particular components of conservation agriculture. Giller et al. (2015) argued that the components of CA should be flexible for farmers and the extent of practice depends on local and farmers' socio-economic contexts. Conservation agriculture does not necessarily

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always increase crop productivity and farmers' incomes for small farmers (Descheemaeker 2020). Farmers who found the components of CA to be useful for them can adopt them according to his/her own preferences. Thus, all components of conservation agriculture should not be applicable as a common approach for all areas. Instead, the practice of CA farming should be flexible and adaptable according to local conditions (Mazvimavi et al. 2010)

Table 1: Extent of CA practice

Particulars	Extent of CA practice			
	Regularly	Occasionally	Rarely	Not at all
Practicing Zero tillage	71	98	29	3
Practicing minimum tillage (strip, reduced, ridge)	152	31	17	1
Leaving crop residue in the field	118	63	15	5
Following crop rotation	109	59	31	2
Maintaining permanent soil coverage	92	71	35	3
Applying green manure	63	51	80	7
Applying vermicompost	148	37	12	4

Table 2: Distribution farmers according to their extent of CA practice

Range of Possible Values	Observed Value	Categories	Farmers No.	Percentage
0-21	5-21	Limited extent (1-7)	39	19.40
		Considerable extent (8-14)	159	79.10
		Large extent (15- 21)	3	1.49
		Total	201	100

Three-Gap model

Table 3 presents the results of the multiple regression. Results show that the know gap is significantly and negatively influenced by CA farming experience, access to machinery, access to extension services, access to CA training, and average income. Several factors, including formal education, farming experience in CA, access to machinery and extension services, CA-related training, and average income, are statistically significant and have a negative impact on the know-how gap.

Table 3: Factors influencing Three-Gap (know, know-can, can-do)

	Know gap		Know can gap		Can-do gap	
Variable			coefficient	P value	coefficient	P value
Education	-0.092	0.213	-0.141	0.051	-0.206	0.006
Age	2.214	0.764	0.154	0.983	3.896	0.601
Farm size	-6.864	0.803	-0.940	0.971	-8.507	0.654
CA farming experience	-0.349	0.000	-0.149	0.003	0.371	0.470
Access to machinery	-0.721	0.000	-0.151	0.047	-0.581	0.066
Training experience	-0.183	0.319	-0.267	0.129	-0.341	0.052
Access to extension service	-0.285	0.018	-0.321	0.005	0.106	0.386
Access to CA training	-0.316	0.012	-0.249	0.039	-0.051	0.687
Average income	-0.474	0.0296	-0.215	0.041	-0.720	0.001
Average physical asset value	0.194	0.248	-0.031	0.846	-0.651	0.000
R2	0.55		0.47		0.44	

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This means that if the value of these factors increases, the Know-cap gap decreases accordingly. Among the explanatory variables, formal education, access to machinery, relevant CA training, average income and value of physical assets were found to be statistically significant. These factors negatively affect the Can-do gap. The results project that access to machinery and average income are commonly significant and significantly influence the three dependent variables – know gap, Know-can gap, and Can-do gap. This indicates that reducing these gaps requires subsidies for resource-poor farmers and easy access to the machinery needed for CA practice.

Extent of Difficulties Faced by the Farmers

Most of the farmers in the study areas started CA under the supervision of several national and international projects related to CA. The farmers were in the treatment group of those projects, and they received incentives and support to practice CA, and almost all CA farmers follow all the components of CA, including the three major principles. But after the completion of the project period, they faced difficulties related to inputs, especially access to machinery and its availability. Thus, the extent of practicing components of CA is decreasing day by day in the study area.

Table 4 shows the PCI for 201 CA farmers and the computed PCI score of the 12 problems, ranging from 314 to 555. The highest PCI score is for the category where the farmers faced the problem of lack of machinery required for CA farming - 157 farmers out of 201 in the study stated this as the major problem to continue CA practice. The selected farmers were not discouraged by their family members and friends, and the PCI score of this problem is the lowest (314) of all the problems.

Table 4: Extent of difficulties

Problems	High	Medium	Low	Not at all	PCI	Rank
There is a lack of specialized machineries in our area	157	41	2	1	555	1
If machineries do not work it is very difficult to repair it, as spare parts are not available in our area	120	65	12	4	502	4
Very few laborers can operate the machineries efficiently	97	52	49	3	444	9
I feel necessity of crop residue for livestock feeding	91	77	31	2	458	7
I feel pest and insects increased in my field	93	62	45	1	448	8
I receive less yield than the previous practice for minimum tillage	64	89	46	2	416	11
I notice weed infestation due to minimum tillage	117	53	29	2	486	6

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Access to extension service is difficult for me	115	63	22	1	493	5
I feel that it is complicated to maintain three principles of CA	82	78	38	3	440	10
Lack of institutional credit for purchasing machineries needed for CA	155	36	9	1	546	2
I think there is a lack of government subsidy/support for CA practice	137	39	21	4	510	3
My family and friends don't encourage me to continue CA	62	45	38	56	314	12

The selected CA farmers were asked to give their opinions on the 12 selected problems that were identified during the pilot study and data collection. After computing the PCI score, the problems were ranked according to the PCI score.

Access to machinery is a critical problem stated by the farmers who are practicing CA, and it has the highest PCI score. This was the major problem faced by the farmers in the study areas. Specialized machinery (power tiller operated seeder, power tiller operated bed planter, power tiller operated strip tillage seeder, etc.) is needed for minimum soil disturbance planting in strip planting mode. Service providers of local machinery are making profits in the farmers' fields on a custom hire basis, but the number of these service providers is not adequate in Bangladesh (Hossain et al. 2014). Bell et al. (2018) suggested that an increase in the adoption and continuation of conservation agriculture practices in agriculture will require easy access for farmers to specialized machinery and an increased supply of machinery. Moreover, the performance analysis of newly invented CA machines is essential, and economic evaluation of CA technology at the field level is crucial for farmers (Tabriz et al. 2021). The 2nd highest PCI score belongs to the problem that farmers do not have easy access to formal credit to purchase inputs, especially the machinery required for CA farming. Formal credit systems (e.g., private or public banks, NGOs) require mortgages, several documents, and complex procedures, which farmers find difficult to manage. Institutional credit can play an important role in purchasing machinery and spare parts of the machinery. The findings of this study are supported by Uddin, Dhar, and Rahman (2017). According to CA farmers' perceptions, they lack government subsidies or incentives to support or continue CA farming. Lack of incentives fails to stimulate the adoption rate among non-CA farmers. Farmers also noticed that if any machinery does not work, then it is very difficult to repair as spare parts for this machinery are not available in local markets– this is the 4th highest constraint mentioned by the farmers. A noticeable number of farmers also stated that they do not have easy access to extension services. This problem has a high PCI score, and it is the 5th highest

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ranked problem, opined to the farmers. Adoption and continuation rates of CA can be increased if the farmers can have easy access to the extension program. Dhar et al. (2018) found the lack of extension services available in the study areas to be a big problem noticed by the farmers, which further corroborates our findings. Access to proper information is strongly correlated with specific technology adoption (Khatoon-Abadi 2011). Chalak et al. (2017) found that farmers who receive practical knowledge and information about farming systems from extension agents have a higher probability of adopting CA farming compared to farmers who mentioned that they merely have contact with extension agents (but no knowledge and training). Farmers who have proper knowledge of CA farming are more likely to have behavioral intention to adopt this farming technique (Tama et al. 2021).

Farmers also noticed weed infestation due to lower tillage compared to conventional farming. The PCI score calculated for this problem is 486, which was the 6th highest PCI score. CA farmers stated that the crop residue that they left on the field could be used as animal feed or as fuel for household cooking. According to the farmers' perception, the PCI score for this problem was 458, ranking 7th in terms of PCI score. Most of the selected farmers stated that leaving crop residues in the field instead of using them for livestock feeding and fuel for cooking is one of the major challenges for them. Dhar et al. (2017) also found that one of the major problems of conservation farming is that farmers cannot use crop residue as animal feed or as fuel for household activities, which is similar to our study's result. The 8th and 9th highest PCI scores belong to the problems of an increase in pest and insect attacks, and the farmers' observation about the lack of experienced labor to operate the machinery, respectively. The PCI scores for the 8th and 9th highest problems were 448 and 444, respectively. According to CA farmers, maintaining the three principles of CA is complex and boring. The PCI score of this particular problem was determined to be 440 and was ranked 10th among 12 problems mentioned by the CA farmers. The 11th highest PCI score belongs to the problem that, due to minimum tillage, CA farmers receive less yield than conventional farming. This has a PCI score of 416. Finally, the 12th and lowest PCI score belongs to the issue of farmers' friends and family members not encouraging them to continue CA farming. This has a PCI score of 314. This result is similar to the findings of Hossain (2017), who identified that peer pressure is a major obstacle in the adoption and continuation of CA in Bangladesh.

Recommendation Matrix

Based on the findings of the study, a set of policy actions is suggested to increase the adoption rate as well as the diffusion of this technology in Bangladesh. The required intervention matrix (Table 5) is presented in three

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categories: policy interventions required, research required, and extension services required.

Table 5: Required intervention matrix for future actions

Items	Actions and policy intervention required	Research required	Extension service required
Provide easy loans for purchasing machinery required for CA farming	√		√
Ensure farmers' easy access to agricultural technology, equipment, and machineries	√		√
Enhance the farmers' knowledge about CA	√	√	√
Arrange training programs on CA regularly			√
Organize 'Field Day' frequently and regularly to discuss the problems faced by farmers in practicing CA			√
Promotional strategies should be increased	√		√
Enhance direct input subsidies	√		
Arrange training program to operate machinery required for CA farming	√		√

Conclusion

This study looked into the challenges that CA farmers face, how much they are using this farming method, and suggested a plan to help improve the use and ongoing practice of CA farming in Bangladesh. Findings of the study reveal that most of the CA farmers were practicing considerable components of CA. The extent of CA practice should be flexible to the farmers' socio-economic, farming, and local conditions. The results also indicate that many farmers opined that the lack of machinery was the major problem in the study area. Thus, this study suggests that providing easy loans to farmers to purchase the machinery required for CA farming is important to stimulate the adoption and continuation rate. Extension service providers can transfer knowledge and updated information about CA farming and discuss the benefits and challenges of CA farming, which can positively influence farmers to continue CA farming. Extension agents can organize "field days" frequently and arrange regular workshops and training programs to discuss the difficulties faced by farmers and provide possible solutions to the farmers in the study areas.

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: The data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Declaration for Human Participants: This study has been approved by the Huazhong Agricultural University, China and the principles of the Helsinki Declaration were followed. Consent to participate: The authors obtained consent from the farmers before interviewing them. They provided oral consent to publish the data.

Authors' Contribution
Riffat Ara Zannat Tama: Conceptualization, Methodology, Investigation, Data Curation and Writing – Original Draft; **Liu Ying:** Software, Validation, Writing- Reviewing and Editing; **Md Mahmudul Hoque:** Visualization and Writing- Reviewing and Editing.

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