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Conservation Agriculture and Household Food Security: A Study of Smallholder Farmers of *Char* Area in Bangladesh

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Abstract—*Food security condition of the char's people is vulnerable. The study focused on to determine factors that affect the adoption of conservation agriculture (CA) among smallholder farmers, assess the profitability of chilli-garlic cultivation, determine the food security level of the households, and assess the constraints and opportunities to adoption of CA in diversified deep water Aman rice-chilli based cropping patterns in Bangladesh. To determine factors that affect the adoption of CA, a probit regression model was used. To determine profitability of chilli-garlic cultivation, profitability equation was used. Food consumption scores were used to determine the food security level of the households. From the probit regression results, age, farm size, level of education, household income, and access of extension services were important in influencing the adoption of CA in the study area. Further results indicate that adoption of CA technology increases per hectare net income from chilli-garlic production compare to non-adapters. Food security level of adapters was much better than non-adapters. This study identified few constraints to adapting CA such as water logging in the paddy field, lack of access extension services etc. This study also identified some opportunities of practicing CA such as weed management, water management etc The paper recommends that there should be improvement in the delivery of extension services in the promotion and dissemination of agricultural technology to improve adoption rates and improve food security status in the study areas.*

Keywords*: Conservation Agriculture, Chilli-Garlic Production, Char Area, Food Security, Bangladesh.*

1. INTRODUCTION

Agriculture is the largest employment sector in Bangladesh. As of 2016, it employs 47% of the total labor force and comprises 14.2% of the country's GDP [1]. The performance of this sector has an overwhelming impact on major macroeconomic objectives like employment generation, poverty alleviation, human resources development and food security. Improving agricultural productivity to meet the demands of an expanding population, in spite of an increasingly unpredictable climate, is one of the foremost challenges Bangladesh is facing.

In Bangladesh, both islands and bars are known as *chars*, but in this article only the vegetated islands within the riverbanks are referred to as chars. *Chars* are nearly accreted from the river and are consequently low lying. Many of the *char* farm lands are under water in the rainy season; that indicates the choice of cropping patterns are limited. About 5% of total population in Bangladesh as well as 6.5 million people live in the *char* areas covering almost 5% of the total land area of the country and miserably it is narrowed as 7200 square kilometer [2]. The economic activities of the char areas are largely based on agriculture, fishing and livestock-rearing. The rural communities of *char* area face multiple livelihood challenges. Their economy is highly dependent on agriculture, resulting in few local employment opportunities for *char* dwellers. Improving agricultural productivity to meet the demands of an expanding population, in spite of an increasingly unpredictable climate, is one of the foremost challenges facing Bangladesh.

Conservation agriculture is an approach to cropping that involves minimal soil disturbance for placing seed and fertilizer, practicing diverse crop rotations and maintaining permanent soil cover with crop residues or plant canopies, managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is characterized by three linked principles, namely: i. Continuous minimum mechanical soil disturbance. ii. Permanent organic soil cover. iii. Diversification of crop species grown in sequences and/or associations. Conservation agriculture as consists of (i) minimum soil disturbance which basically means no soil inversion by tillage, (ii) soil surface cover with crop residues and/or living plants, and (iii) crop rotations, has been referred to as a “unifying label” for a variety of integrated soil and water management practices and agricultural resources [3]. Conservation Agriculture, implicit in this way, provides a number of advantages on global, regional, local and farm level. It provides a really sustainable production system, not only conserving but also enhancing the natural resources and increasing the variety of soil biota, fauna and flora (including wild life) in agricultural production systems without sacrificing yields on high production levels. As conservation agriculture depends on natural processes to work, it improve the biodiversity in an agricultural production system on a micro as well as macro level. No till fields act as a sink for carbon dioxide and conservation agriculture applied on a large-scale could offer a foremost role to manage air pollution in general and global warming in particular. Farmers practicing conservation agriculture could eventually be rewarded with carbon credits. Conservation agriculture is being promoted as a solution to increase agricultural productivity and food security while at the same time preventing erosion and maximizing the conservation functions of the soil [4].

Soil tillage is among all farming operations the single most energy consuming and thus, in mechanized agriculture, an air-polluting, operation. By not tilling the soil, farmers can save between 30 and 40% of time, labour and, in mechanized agriculture, fossil fuels as compared to conventional cropping [5]. When practicing conservation agriculture soil have very high water penetration capacities dropping surface excess and thus soil wearing down significantly. This improves the quality of surface water reducing pollution from soil erosion, and improve groundwater quality. In different areas it has been observed after some years of adopting conservation agriculture that natural springs that had dried up many years ago, happening to flow again.

Conservation agriculture is by no means a low output agriculture and allows yields comparable with modern intensive agriculture but in a sustainable way. Yields be likely to increase over the years with yield variations diminishing. For the farmer, conservation agriculture is mostly attractive because it allows a reduction of the production costs, reduction of time and labour, particularly at times of peak demand such as land preparation and planting and in mechanized systems it reduces the costs of investment and maintenance of machinery in the long term. Cheering the adoption of conservation agriculture requires assurance of long-lasting multiple benefit from adoption, clear-cut and truthful information, and active encouragement [6].

Farmers in Bangladesh, where CA is not practiced everywhere, they face a number of problems which make adoption difficult. These problems are of diverse nature, such as intellectual, social, biophysical and technical, financial, infrastructural and policy. On the basis of above problem, the answer of the following research question were tried to find out through this study. What are the factors that influence the adoption of conservation agriculture in Bangladesh? What are the profitability difference between adapters and non-adapters? What are the food security levels of adapters and non-adapters? What are the constraints and opportunities to adoption of CA in diversified rice-based cropping systems in Bangladesh?

The aim of the study was to assess the factors that influence the adoption of conservation agriculture, its contribution on food security among smallholder farmers. Specifically, the study focused on to determine factors that affect the adoption of CA among smallholder farmers, assess the profitability of chilli and garlic production of adapters and non-adapters, determine the food security level of both adapters and non-adapters households, and assess the constraints and opportunities to adoption of CA in diversified rice-chilli based cropping patterns in Bangladesh

2. MATERIALS AND METHODS

Both primary and secondary data were collected for this research. Cumilla district was purposively selected for this study because of many *Char* (Island) are available there. The study was carried out mainly through a survey of 100 farmers comprising 50 adopters and 50 non-adopters of CA in chili-garlic cultivation with zero tillage after deepwater *Aman* rice harvesting. Multi-stage sampling procedure was used to select households for data collection. A semi-structured questionnaire was used to obtain farm and household level information from adopters and non-adopters. Food consumption scores were used to determine the food security level of the households. Statistical Package for Social Scientists (SPSS) was used to analyze data where descriptive and inferential statistics was obtained. Per hectare profitability of chilli-garlic production of adapters and non-adapters was measured in terms of gross margin, net return and benefit cost ratio.

Analytical Framework for Farmers' Adoption of CA

From the conceptual framework, household decision to adopt CA depends on a number of factors like age, farm size, level of education, household income, and access of extension services and unobservable factors explained by the stochastic term, ε. This study used the probit model to assess the determinants of CA adoption.

In this study, it was assumed that household adopts any technology by comparing the basic benefit of that technology to the current one. Benefits of CA may include high yield, which reduces the farmers' vulnerability to food insecurity. The other benefit could be reduced labour that may allow the farmer to allocate his time to other enterprises and income generating activities. Therefore, all things constant, farmers will adopt CA if the net benefits are positive.

We assumed a latent variable Y_i^* representing adoption or non-adoption. Where adoption means the process by which a particular farmer is exposed to, considers and finally practices an innovation. Independent variables Xi be regarded as factors that affect CA adoption and β be a K- vector of parameters. Then the decision to adopt a technology can be specified as follows [7].:

Yi* = βXi + εi .... (1)

Where:

We observe Yi= 1 if Yi* > 0 and Yi = 0 if otherwise.

Y =1 if the household adopts the CA technology and Y=0 if the household decides otherwise.

In this case Prob (Y=1/X) = F(X,β) .... (2)

Prob (Y=0/X) = 1-F(X,β) .... (3)

Then

F(X, β) = X β

Limiting Xβ to (0, 1)Prob(Y=1/X) - ∞∫Xβ Φ(t)dt = Φ (Xβ) (4)

Such that Prob (Y = 1)= Φ (βX)............ .(5)

Where Φ (.) is function of standard normal distribution function.

Assessing the Profitability of Chilli-Garlic Production

For profitability analysis, activity budgets of the chilli-garlic cultivation were prepared using the following algebraic equation [8]:

$$\pi = P_y Y - \sum_{i=1}^{n} (P_{xi} X) - TFC$$

π = Net return (Tk./hectare);

P_y = Per unit price of the product (Tk./kg);

Y = Quantity of the production per hectare (Kg);

P_{xi} = Per unit price of i^{th} inputs (Tk.);

X_i =Quantity of the i^{th} inputs per hectare (kg);

TFC= Total fixed cost (Tk.);

i=1,2,3…………….,n (number of inputs).

In order to compare the level of food security between adapters and non-adapters, food consumption score (FCS) was used in this study. The FCS is a frequency weighted diet diversity score calculated using the frequency of consumption of different food groups consumed by a household during the 7 days before the survey. FCS is a relatively new food security indicator, and as such its reliability and accuracy is still under

WFP's corporate FCS thresholds

The thresholds for the FCGs should be determined based on the frequency of the scores and the knowledge of the consumption behavior in that country.

Bangladesh specific FCS thresholds

Given the importance of oil and fish in the diet of the Bangladeshi people, these thresholds were elevated. As a result, FCS thresholds were revised for Bangladesh and four food consumption groups were created:

- Poor consumption (≤28),
- Borderline Consumption (>28 and ≤42),
- Acceptable Consumption (>42).
- An additional threshold was introduced to distinguish the acceptable households between acceptable low (43-52) and acceptable high (>52) [9].

3. RESULTS AND DISCUSSION

Determinants of CA Adoption

This study assessed the influence of household head age, farm size, level of education, household income, and access of extension services on household decision to adopt CA using Probit model. The Log Likelihood function significant at 1% also shows that when independent variables were taken together, they strongly influenced household decision to adopt CA in the study area. Likewise, a χ2 statistic of 36.89 showed that the overall model was significant at 1% level signifying fitness of the model. This shows that the explanatory variables are relevant in explaining the adoption decision. The results are summarised in the Table 1 below.

Table 1: Determinants of CA

Variables	Coefficient	Std. Error	Marginal effects
Intercept	-4.9850	1.4983***	
Age	0.1630	0.0595**	0.0618
Farm size	0.1991	0.1701*	0.1101
Level of education	0.369	0.1698**	0.1601
Annual family income	-0.0015	0.0006**	-0.0005
Family size	-0.0160	0.01350	-0.0059
Access of extension services	1.2731	0.4213***	0.4187
Log-likelihood	-69.0758		
χ2	36.89		
Probability of χ2	0.000***		
N	100.000		

Note. ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level
Source: Author's analysis

The results showed that household head age, farm size, level of education, household income, and access of extension services were important factors in influencing household decision to adopt CA.

Age of household head has positive influence on adoption of CA and it was statistically significant at 5%. The marginal effect indicated that increase in number of years of household head age by one year would increase household probability of adopting CA by 6.1%. The parameter was more imperative because older people had more farm ownership rights than their younger counterparts. In addition older people are often more experienced and knowledgeable than younger ones [10] and this helped them to make informed decision about CA adoption. Farm size of the household was found positively to adapt CA and was significant at 10%. The marginal effect of farm size showed that if the household farm size increases by one hectare there is 11% more chance of adaption CA. Education level of the household head was found to influence positively towards adoption of CA and was significant at 5%. The marginal effect of education showed that if the household head increases education level by one year there is 16% more chance of adopting CA. Education helps farmers to analyse alternatives critically and forecast the expected benefits to their activities [11]. The parameter estimate for household access to agricultural extension showed a positive relationship and was statistically significant in influencing household decision to adopt CA at 1%. The parameter's marginal effect indicated that households that have access to agricultural extension services have 41% higher probability of adopting CA than those with no access to extension services. In other words, increase in acquired knowledge about CA technology increased household chances of making an informed decision for CA adoption. Increased agricultural extension services access increases chances of adoption or participation and builds confidence of adopters to succeed. It is logical to expect that if a farmer has a better extension media contact then the famer is likely to understand benefits of CA and decide to adopt CA. This finding reflects that without knowledge of the practices associated with CA via some information or communication channel, adoption is improbable.

Profitability of Chilli - Garlic Production of Adopters and Non-adopter

The main purpose of this part is to estimate the costs and returns of chilli-garlic production. For calculating the costs and returns of chilli and garlic production, the cost items were classified into two groups, (i) Variable cost and (ii) Fixed Cost. Variable cost included the cost of all variable factors like human labor, land preparation, seed, fertilizer, irrigation water, insecticides and pesticides. On the other hand, fixed cost was calculated for interest on operating capital and land use cost. On the return side, gross return, gross margin, net return, BCR (Benefit Cost Ratio) were determined in this part.

Table 2: Cost of Chilli-Garlic Production (dry) Per Hectare

	Unit	Adapters		Non-adapters	
Items of cost		Quantity	Cost (Tk.)	Quant.	Cost (Tk.)
A. Variable cost					
Human labour	Man-day	150	60000.00	275	110000.00
Draft and power tiller	Tk.	-	-	-	10200.00
Chilli seed	Kg	32	4160.00	30.5	3965.00
Garlic seed	Kg	152	7600.00	150	7500.00
Fertilizer					
Organic	Kg	-	-	5650	2825.00
Inorganic	Kg	400	16000.00	650	26000.00
Pesticide	Tk.	-	7400.00	-	7750.00
Irrigation	Tk.		2500.00		7500.00
Total variable cost			97660.00		175740.00
B. Fixed cost					
Interest on operating capital @ of 12% for 6 months	Tk.		5859.60		10544.40
Land use cost	Tk.		24500.00		24500.00
Total fixed cost			30359.60		35044.40
C. (A+B) Total cost			128019.60		210784.40

Source: Field Survey, 2018

Gross Return of Chilli - Garlic Production

Per hectare gross return was calculated by multiplying the total amount of chilli by average farm gate price and total amount of garlic multiplying by average farm gate price. The average yield of chilli (dry) per hectare was 2587.41 kg and 2187.33 kg and the average yield of garlic was 2190.21 kg and 2247.40 kg for adapters and non-adapters, respectively. It may be noted here that the price of dry chilli was reported to be Tk. 125 per kg and garlic price was Tk.50 per kg. which were the average farm gate prices in the study area(Table 3).

Gross margin is the return over variable cost. Gross margin was obtained by deducting total variable cost from gross return. Per hectare gross margin was estimated at Tk. 335276.75 and Tk. 210046.25 for adapters and non-adapters, respectively. In the present study, net return was estimated by deducting total cost from gross return. Per hectare net return was calculated at Tk. 304917.15 and 175001.85 for adapters and non-

Table 3: Comparative Economic Statement of Chilli (dry) -Garlic Production

Measuring criteria	Adapters	Non-adapters
Yield Chilli (kg) Garlic (kg)	 2587.41 2190.21	 2187.33 2247.40
Gross return (Tk.) (Amoun.Chilli (kg) X Tk.125) (Amoun.Garlic (kg) X Tk. 50)	432936.75 (323426.25) (109510.50)	385786.25 (273416.25) (112370.00)
Total Variable cost (Tk.)	97660.00	175740.00
Total Fixed cost	30359.60	35044.40

Total Cost	128019.60	210784.40
Gross Margin (Tk.)	335276.75	210046.25
Net Return	304917.15	175001.85
BCR (undiscounted)	3.38	1.83

Source: Field Survey, 2018

adapters, respectively. Benefit cost ratio (BCR) is a relative measure which is used to compare benefit per unit of cost. BCR was estimated at 3.38 and 1.83 for adapters and non-adapters, respectively, which indicated that dry chilli-garlic production was profitable in the study area. The production of chilli-garlic was more profitable for the CA adapters than the non-adapters as the BCR for adapters was 3.38 whereas the BCR for non-adapters was 1.83.

Food Consumption Scores

Food consumption scores of sample household are presented in Table 4. There were 4% and 20% of household having poor food consumption for adapters and non-adapters, respectively. The table 5 also shows that boarder consumption, acceptable low consumption and acceptable high consumption for the adapters were 8%, 50%, and 38%, respectively and for the non-adapters these figures were 38%, 24% and 18%, respectively. We can observe from the table 4 that the adapters of the conservation agriculture were did not only earned more revenue but also had more food security compared to non-adapters of the conservation agriculture.

Table 4: Percentage of Food Consumption Score for Adapters and Non-adapters

Profile	Adapters		Non-Adapters	
	No. of respondent	%	No. of respondent	%
Poor consumption (≤28)	2	4	10	20
Borderline Consumption (>28 and ≤42)	4	8	19	38
Acceptable Consumption low (43-52)	25	50	12	24
Acceptable Consumption high (>52)	19	38	9	18
Total	50	100	50	100

Source: Field Survey, 2018

So, if our focus on to alleviate poverty and achieving food security in the *char* area, we can suggest them to adopt conservation agriculture technology when it is feasible.

Constraints of Adapting Conservation Agriculture

The farmers were asked to mention the specific problems concerned by them in CA practice. The problems identified by the farmers are listed below according to their importance in the Table 5.

Table 5: Constraints of CA as ranked by farmers

Problem	Number of times problem was ranked					
	1st	2nd	3rd	4th	Total (50)	%
Water logging in the paddy field	5	10	13	10	38	76
Lack of access extension services	5	8	10	7	30	60
Dependency on paddy cultivation	7	4	10	13	34	68
Crop residue was not used as fuel	4	7	11	7	29	58
Every year similar cropping pattern	18	11	5	7	41	82

Source: Field Survey, 2018

The information presented above showed that the extent of adoption of CA practice was mostly hindered due to every year similar deep water *Aman* rice-chilli cropping pattern, water logging in the paddy field, dependency on paddy cultivation, lack of access to extension services, and crop residue cannot be used as fuel. If the rainy season water long time after harvesting of deep water *Aman* rice, Chilli-Garlic cultivation tends to be delay that impact on yield. In terms of information accessibility and farmer capability improvement, agricultural extension is a critical public service. , if they lack the information on how best to implement recommended practices, they may fail to do so, because they lack the technical knowhow to adopt them optimally and profitably[12]. Practicing conservation agriculture regarding chilli-garlic cultivation fully depend on backward link with deep water *Aman* rice cultivation. If any farmer does not cultivate deep water Aman rice he cannot practice conservation agriculture for chilli-garlic production. Most of the farmers in Bangladesh use their crop residue as cooking fuel, conservation agriculture disallow them from using crop residue for this purpose. The *Cha*r area in Bangladesh, the cropping patters are limited. As chilli-garlic cultivation is fully depend on deep water *Aman* rice cultivation, they are somehow bound to follow similar cropping patter every year.

Opportunities of Adapting Conservation Agriculture

The farmers were asked to mention the specific opportunities observed by them by practicing CA. The opportunities identified by the farmers are listed below according to their importance in the Table 6.

Table 6: Opportunities of CA as ranked by farmers

Opportunities	Number of times opportunity was ranked					
	1st	2nd	3rd	4th	Total (50)	%
Protection of soil erosion	12	7	5	8	32	64
Fertilizer management	8	7	12	10	37	74

Water management	15	12	8	11	46	92
Pests management	8	7	10	6	31	62
Weed management	26	13	5	4	48	96

Source: Field Survey, 2018

The information presented above showed that practicing CA creates opportunities mostly for weed management, water management, fertilizer management, protection of soil erosion, and pests management. Conservation agriculture create great opportunity to protect soil erosion which help the marginal farmers many of them live below the poverty line. Soil erosion, along with other environmental threats, particularly affects these farmers by diminishing yields that are primarily used for subsistence[13]. CA systems have various crop mix including legumes, and nutrients are stored in the soil organic substance, nutrients and their cycles must be managed more at the system or crop combine level. Thus, fertilization would not anymore be strictly crop specific, with the exception of nitrogen top dressing [14]. Conservation agriculture has great opportunity to increase water content in the soil. No-till and CA increased soil water content (0–60 cm) compared to conventional tillage by an average of 20 mm. [15]. Conservation agriculture work on same principles of integrated pest management (IPM) to help amplify biodiversity and conservation of natural resources. In addition, recent advances in insect pest management like biointensive IPM and biotechnology can also synergize the insect pest management in the conservation agriculture management system [16]. . In conservation agriculture weeds expression is complex and differ from conventional systems. Because of minimum or no tillage of the soil and the flora that thrives in conservation agriculture. Reduced tillage systems affect the efficacy of herbicides and mechanical weed control measures[17].

4. CONCLUSION

The practice of conventional agricultural practices specially the deep tilling of soil has more and more become concerned with the health of agro-ecosystems and eventually wide-ranging food security. From the findings, several factors such as age of the household head, education level of the household head, increasing access to extension services and land holding size of the household were found to be influencing the probability of adoption of conservation agriculture. This practice helped the farmers to minimize their labour and other input cost, maximize net return of chilli-garlic production. A positive relationship exist between conservation agriculture adoption and achievement of food security status. The contribution of conservation agriculture adoption on food security is also evident through increased frequency of meals per day, increased household income and increasing purchasing power among adopters. The study identified some constraints which the farmers were facing while adopting conservation agriculture such as similar cropping pattern every year, water logging in the paddy field, fully depend on paddy cultivation, lack of access to extension services, and crop residue cannot be used as fuel. The study also found some opportunities of adopting conservation agriculture such as soil management, fertilizer management, water management, pest management, and weed management. Overall results show consistently that conservation agriculture adopters were better off than non-adopters.

Considering the findings of the study, some essential policy recommendations have been arisen which are: the importance of improved access to formal education should not be undermined. This would help the ability of farmers in knowledge acquisition and quick understanding of technology components; government extension service could improve access to information about CA technology to farmers. The implication of this is that farmers' access to extension services should be improved when promoting conservation agriculture technology among smallholders in the areas of study in particular and Bangladesh in general.

5. CONFLICT OF INTEREST

The authors declare no conflicts of interest in this paper.

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