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Conservation Agriculture Practice in Bangladesh: Farmers' Socioeconomic Status and Soil Environment Perspective

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***Abstract*—**The study was conducted to assess the impact of conservation agriculture practice on farmers' socioeconomic condition and soil environmental quality in Bangladesh. A total of 450 (i.e., 50 focal, 150 proximal and 250 control) farmers from five districts were selected for this study. Descriptive statistics like sum, averages, percentages, etc. were calculated to evaluate the socioeconomic data. Using Enyedi's crop productivity index, it was found that the crop productivity of focal, proximal and control farmers was increased by 0.9, 1.2 and 1.3 percent, respectively. The result of DID (Difference-in-difference) analysis indicated that the impact of conservation agriculture practice on farmers' average annual income was significant. Multidimensional poverty index (MPI) indicates that poverty in terms of deprivation of health, education and living standards was decreased; and a remarkable improvement in farmers' socioeconomic status was found after adopting conservation agriculture practice. Most of the focal and proximal farmers stated about increased soil environmental condition where majority of control farmers stated about constant environmental condition in this regard. The Probit model reveals that minimum tillage operation, permanent organic soil cover, and application of compost and vermicompost were found significant factors affecting soil environmental quality under conservation agriculture. Input support, motivation, training programmes and extension services are recommended to implement in order to raise the awareness and enrich the knowledge of the farmers on conservation agriculture practice.

***Keywords*—**Conservation agriculture, crop productivity, socioeconomic status, soil environment quality.

I. Introduction

AGRICULTURE is the heart of Bangladesh economy where more than 80% farmers are smallholder having land less than 1.0 hectare. The rural economy constitutes a significant component of the national GDP with agriculture accounting for 17.2% [1]. As a result of 'Green Revolution', Bangladesh had attained self sufficiency in food production for a shorter period, but long term use of chemical fertilizers and pesticides resulted in decreased soil fertility and productivity [2]. In this context, conservation agriculture is becoming increasingly important in overcoming the problems of declining agricultural productivity in a developing country like Bangladesh. Conservation agriculture is defined as a resource-conserving technology for crop production which endeavors to attain satisfactory profits alongside high and sustained production levels while concomitantly conserving the environment following the principles of minimum tillage operation, crop residue management and diversified crop rotations [3]. Although conservation agriculture intends to help farmers for earning more money income with minimum amount of labour, water and other production input costs; maintain land healthy and productive; and protect natural environment [4]; about 8-10% farmers around the world follow this practice [5], [6].

In economic sense, this farming system shows improved performance than traditional farming. Reduction in input use may help to get benefits forward by declining the crop production cost. Practicing minimum tillage can make a reduction in the production cost for a certain crop. Less tillage of the soil can reduce labour, fuel, irrigation and machinery and increase yield because of higher water infiltration, storage capacity and less erosion. By reducing tillage, decomposing crop residues where they lie and by growing winter cover crops, carbon loss can be slowed and reversed eventually. Cover crops may reduce the cost of labour and high external energy inputs for subsequent crops. Using a leguminous cover crop in one crop season can help to decrease the necessity for nitrogen fertilizer for the succeeding crop, and hence decrease the fertilizer costs. Modalities show that using organic soil cover has a positive effect on crop yield also. Crop yield can be amplified by more or less 21% by the usage of cover crops [1], [7]. Crop rotations, especially those involving three or more crops, have the potential to increase the crop yield compared to conventional crop rotations [8], [9].

The real life scenarios of smallholder farmers expose that unsustainable farming methods in corporation with excess ploughing, monocropping and little/zero replenishment of nutrients through generations have been resulted in stern diminution of the soil, the ultimate consequence of which is decreased yields. A farming practice like conservation agriculture has the potential to enhance the pulse of farmers' livelihood. The labour input in this practice could be reduced by almost 75% [10]-[12]. The time saved under conservation agriculture allows farmers to dedicate more time to other more profitable non-farm occupations. More time availability offers real opportunities for diversified options. For women, it provides opportunities to engage themselves in other income generating and socioeconomic activities while also sparing more time to take care of the family.

Soil environmental problems caused by conventional agricultural practice mainly include water contamination and

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tillage induced carbon-di-oxide (CO_2) losses. Practicing conservation agriculture assists agricultural ecosystem to help control agricultural pests; maintain biodiversity; maintain soil fertility; contribute to climate stability; purify water and air; and regulate disease carrying organisms. Soil, containing high amount of carbon with crop residues on the surface are very effective in increasing soil organic matter that allows a buffering capacity on soil temperature, and improve its structure and hydraulic conductivity [13], [14]. Conservation agriculture practice can offset carbon emission through land use and fossil fuel combustion. This practice is a win-win situation as agriculture wins with improved food and fiber production, and society wins with the enhanced environmental quality. Cover crops bind the soil particles into aggregates and recycle soil nutrient that influence the biological community in the soil.

There exist a good number of literatures that describe the modalities of such farming practice. A reticent effort has been made here to review the earlier research studies which are: [12] evaluated the impact of conservation agriculture practice on farmer's livelihood status in Bangladesh and found a remarkable improvement in farmers' livelihood condition after adopting conservation agriculture. Reference [15] carried out a research on conservation agricultural technologies in diverse cropping systems in Bangladesh and found that 39.30% respondents practiced crop rotation and 30% respondents practiced mixed cropping, and most of them experienced increased production. Reference [16] performed productivity and efficiency analysis of maize under conservation agriculture practice in Zimbabwe and indicated that farmers produced 39% more output in conservation agriculture practice compared to conventional farming practice. Reference [17] reviewed the environmental impact of conventional, organic and conservation agriculture, and showed that conservation agriculture was more efficient in building soil organic matter than organic agriculture and conventional agriculture with less emission of nitrogen and greenhouse gases.

The literature reviews clearly indicate that most of the studies dealt with either economic, livelihood or environmental aspects of conservation agriculture practice though these are not in the context of Bangladesh. Therefore, to minimize the research gap, this research would be helpful at examining the socioeconomic issues on enhancement of livelihood of farmers through adoption of conservation agriculture along with its crop profitability and soil environmental benefits. The specific objectives of the study are: i) to examine the impact of conservation agriculture practice on improving the socioeconomic status of the farmers; and ii) to assess the impact of conservation agriculture practice on soil environmental quality in relation to conventional agriculture practice.

II. Materials and Methods

The study was conducted in five agro-ecological zones of Bangladesh which were: Mymensingh, Bogra, Tangail, Sherpur and Jamalpur; the major crops taken under the study consideration in the following districts were: potato, bean, pineapple, rice and wheat, respectively. Three categories of farmers were targeted for investigation namely, focal, proximal and control farmers. Focal farmers received technical and logistic support for practicing conservation agriculture from the project, and had regular contact with extension support staff; proximal farmers were the neighboring farmers of focal farmers who received indirect support like technical advice and had occasional contact with the extension staff; and control farmers received no training or technical support on conservation agriculture from any organization and the project staff. In each locale of the study, a total of 90 farmers (10 focal, 30 proximal and 50 control) were selected; of which focal farmers were selected purposively, and proximal and control farmers were selected randomly. Thus, a total of 450 farmers were selected as the sample for observation and data collection. Questionnaire survey, focus group discussion (FGD) and key informant interview (KII) were done to collect the primary data. Secondary sources of data having relevance with this study included handouts, reports, publications, notifications, etc.

III. Analytical Techniques

A. The Enyedi's Index of Crop Productivity Measurement

To measure the productivity of respective crops in the research areas compared to the entire regions, the Enyedi's index was used [18]. For calculation, (1) was used:

$$\text{Crop productivity} = (YT_n \div Y_nT) \times 100 \quad (1)$$

where, Y = Production of the respective crop in the unit area; Y_n = Total production of the crop in the entire region; T = Cultivated unit area under the respective crop; and T_n = Cultivated area in the entire region under the respective crop.

B. Difference-in-Difference Analysis

DID analysis was done to measure what would have occurred without the project intervention, and to evaluate the difference between the past and present situation after the project intervention [12], [19]. (2)-(4) was used for estimating DID results:

$$DID_{FP} = (F_1 - P_1) - (F_0 - P_0) \quad (2)$$

where, F_0 = Income level of focal farmers (before project intervention); F_1 = Income level of focal farmers (after project intervention); P_0 = Income level of proximal farmers (before project intervention); and P_1 = Income level of proximal farmers (after project intervention).

$$DID_{FC} = (F_1 - C_1) - (F_0 - C_0) \quad (3)$$

where, F_0 = Income level of focal farmers (before project intervention); F_1 = Income level of focal farmers (after project intervention); C_0 = Previous income level of control farmers; and C_1 = Current income level of control farmers.

$$DID_{PC} = (P_1 – C_1) – (P_0 – C_0) \quad (4)$$

where, P_0 = Income level of proximal farmers (before project intervention); P_1 = Income level of proximal farmers (after project intervention); C_0 = Previous income level of control farmers; and C_1 = Current income level of control farmers.

C. Multidimensional Poverty Index (MPI)

The MPI was constructed to appraise the intensity of poverty of the farmers in the study areas. It is composed three equally weighted poverty dimensions namely health, education and living standards. The health dimension comprises two equally weighted indicators: nutrition and child mortality; the education dimension comprises two equally weighted indicators: years of schooling and child enrolment; and the living standards dimension comprises six equally weighted indicators: cooking fuel, sanitation, water, electricity, floor and assets [12], [20], [21]. (5) was used to appraise the intensity of poverty.

$$\text{Intensity of poverty} = \{\Sigma\ c(k)\} \times 100 \quad (5)$$

where, c = Households deprived of the indicators; k = Weighted score of the indicators; and q = Average household size in each area.

D. Percentage Perception Index (PPI)

To evaluate whether there was improvement in soil environmental quality through adopting conservation agriculture practices, percentage perception index (PPI) was used [22]. Each farmer of the research areas was asked to indicate his/her option regarding each level of improvement on ten (10) selected opinions. Farmers had option to indicate each as, ‘increase’, ‘decrease’ and ‘constant’ with a corresponding score of 1, 2 and 0, respectively for the statements. To see the percentage of each statement, (6) was used:

$$PPI = [\text{No. of respondents' opinion about statements (increase, decrease or constant)} \times 100] \div \text{Total no. of respondents} \quad (6)$$

E. Probit Model

In order to investigate the extent of influence of the factors under conservation agriculture practice on soil environmental quality, probit model was used [23]. (7) was used to identify the level of influence of the factors influencing soil environmental quality.

$$Z_i = \Phi^{-1} (P_i) = \beta_0 + \beta_1Q_1 + \beta_2Q_2 + \beta_3Q_3 + \beta_4Q_4 +\beta_5Q_5 + \beta_6Q_6 + U_i \quad (7)$$

where, Φ = Cumulative distribution function of an explanatory variable [$F(Q) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\beta_0+\beta_i Q_i} e^{\frac{-Z^2}{2}} dZ$] that follows normal distribution with mean μ and variance σ^2; P_i is the probability of improving soil environmental condition or not (P_i = 1 indicates improved condition and P_i = 0 indicates otherwise); Z_i = Improvement in soil environmental quality; Q_1 = Minimum tillage operation (P_i = 1 indicates practicing minimum tillage and P_i = 0 indicates otherwise); Q_2 = Permanent organic soil cover (P_i = 1 indicates keeping soil cover and P_i = 0 indicates otherwise); Q_3 = Diversified crop rotation (no. of cops per rotation); Q_4 = Application of cowdung and bioslurry (kg); Q_5 = Application of compost and vermicompost (kg); Q_6 = Implementation of IPM technology (gm of pheromone); β_0 = Intercept; β_1 to β_6 = Regression coefficients of the explanatory variables; and U_i = Error term.

The marginal probabilities of the key determinants of improving soil environmental quality were estimated using (8) based on the expressions derived from the marginal effect of the probit model.

$$dZ/dQ = \beta_i\varphi\ [\Phi^{-1}(P_i)] \quad (8)$$

where, β_i = Estimated probit regression coefficient with respect to the i^{th} factor; φ = Standard normal probability distribution function [$f(Q) = \frac{1}{\sqrt{2\pi}} e^{\frac{-Z^2}{2}}$]; Φ = Standard normal cumulative distribution function; and P_i = Estimated probability of soil environmental quality improvement.

IV. Results and Discussion

A. Socioeconomic Status of the Selected Farmers

Table I represents the basic information of the selected farmers in the study areas. It is found that average household and farm size of focal, proximal and control farmers were 5.0, 5.0 and 6.0; and 0.48, 0.41 and 0.52, respectively. Average dependency ratio of focal farmers (1.4) was comparatively lower than proximal and control farmers (1.7 and 3.0), respectively which indicated that focal farmers were more self-sufficient and self-employed.

TABLE I
BASIC INFORMATION ABOUT THE SELECTED FARMERS

Particulars		Farmers' categories		
		Focal	Proximal	Control
Average household size (no.)		5.0	5.0	6.0
Average farm size (ha)		0.48	0.41	0.52
Average dependency ratio (no.)		1.4	1.7	3.0
Average sex distribution (% of farmers)	Male	68.0	70.0	69.2
	Female	32.0	30.0	30.8
Average age (years)		34	37	36
Literacy rate (% of farmers)	Illiterate	32.0	56.0	55.6
	Sign only	42.0	27.0	22.4
	Primary and above	26.0	17.0	22.0
Occupational status (% of farmers)	Agriculture only	24.0	28.0	29.2
	Agriculture and others	76.0	72.0	70.8
Farming systems practiced (% of farmers)	Subsistence	18.0	29.0	21.0
	Commercial	82.0	71.0	79.0

The percentages of male and female respondents were 68.0, 70.0 and 69.2; and 32.0, 30 and 30.8 for focal, proximal and control farmers, respectively. Average age of focal, proximal and control farmers was 34, 37 and 36 years, respectively. In the study areas, 42.0 percent focal farmers could put sign only but majority of the proximal and control farmers (56.0 and

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55.6 percent, respectively) were illiterate. Majority of them (76.0, 72.0 70.8 percent focal, proximal and control farmers, respectively) were occupied in farming as well as other income generating activities like wage labour, van/rickshaw pulling, petty business, etc. Majority of the farmers in the study areas were commercial farmers (82.0, 71.0 and 79.0 percent focal, proximal and control farmers, respectively) (Table I).

B. Adopter Categories

Reference [24] defined an adopter category as a classification of individuals within a social system on the basis of innovativeness and suggested a total of five categories of adopters in order to standardize the usage of adopter categories in diffusion research. The categories of adopters are: innovators, early adopters, early majority, late majority and laggards.

TABLE II
TREND OF ADOPTING CONSERVATION AGRICULTURE PRACTICE BY THE FARMERS

Adopter categories	Trend of adoption	
	[a]N = 50	Percentage of farmers
Innovators	3	5.0
Early adopters	8	15.0
Early majority	14	30.0
Late majority	17	35.0
Laggards	8	15.0

[a]Number of farmers

It is evident from the Table II that in case of adopting an innovation like conservation agriculture, the percentages of innovators were 5.0%, early adopters were 15.0%, early majority were 30.0%, late majority were 35.0% and laggards were 15.0%. Though majority of the farmers were cynical about this farming practice at the beginning, the adoption of this practice was ultimately successful.

C. Nature of Adopting Conservation Agriculture Practice

Before adopting conservation agriculture, the farmers of each category in the study areas were fully dependent on usage of synthetic fertilizers, pesticides and medicines in some cases. After adopting conservation agriculture, focal farmers followed the basic principles of conservation agriculture. Proximal farmers observed the farming practices of focal farmers' and tried to follow them, but control farmers did not follow any principle of conservation agriculture rather they continued traditional crop farming practices.

It is observed from the Table III that focal farmers adopted fully the principles of practicing zero/minimum tillage and retaining crop residue. As the selection of appropriate crop rotation is a lengthy process, it was partially adopted by them. It was not possible for them to diminish the use of synthetic fertilizers fully, but they practice to use full doses of organic fertilizers (compost, vermicompost, cowdung and bioslurry) and IPM technology; and no usage of pesticides, herbicides and medicines.

Proximal farmers fully adopted such practice only by retaining crop residue, and using compost, cowdung and bioslurry. They partially adopted fertilizers, pesticides and herbicides use. No control farmer on the contrary practiced zero/minimum tillage, retained crop residue or practiced appropriate crop rotation. They continued to use full range of synthetic fertilizers, pesticides, herbicides and medicines; and partial usage of cowdung and bioslurry (Table III).

TABLE III
NATURE OF CONSERVATION AGRICULTURE PRACTICE ADOPTED BY THE FARMERS

Particulars	Farmers' categories		
	Focal	Proximal	Control
Practicing zero/ minimum tillage	ȣ[a]	ɵ[c]	ɵ[c]
Retaining crop residue	ȣ[a]	ȣ[a]	ɵ[c]
Practicing crop rotation	ϫ[b]	ɵ[c]	ɵ[c]
Using synthetic fertilizers	ϫ[b]	ϫ[b]	ȣ[a]
Using synthetic pesticides	ɵ[c]	ϫ[b]	ȣ[a]
Using herbicides	ɵ[c]	ϫ[b]	ȣ[a]
Using medicine	ɵ[c]	ɵ[c]	ȣ[a]
Using compost	ȣ[a]	ȣ[a]	ɵ[c]
Using vermicompost	ȣ[a]	ɵ[c]	ɵ[c]
Using cowdung	ȣ[a]	ȣ[a]	ϫ[b]
Using bioslurry	ȣ[a]	ȣ[a]	ϫ[b]
Using IPM technology	ȣ[a]	ɵ[c]	ɵ[c]

[a]Full adoption; [b]partial adoption; and [c]no adoption.

D. Measurement of Crop Productivity

The crop productivity in the study areas in comparison with the crop production in the entire region was estimated using the Enyedi's crop productivity index (Table IV). It is seen that per hectare crop production in case of focal, proximal and control farmers was 141.4, 140.1 and 140.5 quintal, respectively before adopting conservation agriculture which was increased to 142.6, 141.7 and 142.3 quintal per hectare, respectively after practicing conservation agriculture. Before adopting conservation agriculture, total cultivated area in the entire region was 4856 ha and after adopting this practice, it was 4862 ha. Total crop production in the entire region was augmented to 1035548.4 quintal from 1034825.4 quintal after adopting conservation agriculture. Information on total cultivated area and production in the entire region had been collected from [1], [25], [26].

TABLE IV
ENYEDI'S CROP PRODUCTIVITY INDEX (IN AVERAGE)

Particulars	Farmers' categories					
	Focal		Proximal		Control	
	Before	After	Before	After	Before	After
Production (quintal/ha)	141.4	142.6	140.1	141.7	140.5	142.3
Total production in the entire region (quintal)	1034825.4	1035548.4	1034825.4	1035548.4	1034825.4	1035548.4
Cultivated area (ha)	0.47	0.47	0.47	0.47	0.47	0.47
Total cultivated area in the entire region (ha)	4856	4862	4856	4862	4856	4862
Crop productivity (%)	141.2	142.5	139.9	141.6	140.3	142.2
Change in crop productivity (%)	0.9		1.2		1.3	

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The crop productivity of focal, proximal and control farmers would be increased from 141.2, 139.9 and 140.3 percent to 142.5, 141.6 and 142.2 percent, respectively with respect to the entire region if their entire cultivable land would be taken under consideration to produce crop following all the principles of conservation agriculture (average farm size of 0.47 ha for all categories of farmers). If practicing conservation agriculture would be continued, crop productivity was expected to increase in the next years of crop production. The result is somewhat related to [27] where the authors found that in the first few years of crop residue retention, farmers experienced moderately reduced yields but yields were regained by the following years after having properly managed systems.

E. Impact of Conservation Agriculture on Farmers' Annual Income

Farmers' sources of money income are represented in Table V which were: farm and non-farm income. Farm income indicated income from crops, livestock (large animal i.e., cow, ox, goat, sheep, etc.; and small animal i.e., poultry, duck, etc.), fishery, agroforestry and others. Non-farm income considered income from small business, wage labour, shopkeeping and other income generating sources.

TABLE V
AVERAGE ANNUAL INCOME OF THE FARMERS

Sources of income		Farmers' categories								
		Focal			Proximal			Control		
		Before (Tk.)	After (Tk.)	Change (%)	Before (Tk.)	After (Tk.)	Change (%)	Before (Tk.)	After (Tk.)	Change (%)
Farm income	Rice	28056	30192	7.6	28301	30121	6.4	28342	30033	6.0
	Vegetables	33220	36406	9.6	32345	34726	7.4	32957	35132	6.6
	Fruits	8602	9095	5.7	8759	9177	4.8	8621	8973	4.1
	Agroforestry	1675	2043	22.0	1786	1995	11.7	1784	1967	10.3
	Livestock	8159	9280	13.7	8747	9672	10.6	9142	9855	7.8
	Fisheries	700	850	21.4	624	801	28.4	691	824	19.2
	Others	1849	2079	12.4	1872	2023	8.1	1956	2042	4.4
Total farm income		82261	89945	9.3	82434	88515	7.4	83493	88826	6.4
Non-farm income	Small business	15627	17390	11.3	15647	17325	10.7	15612	16572	6.1
	Wage labour	10308	10712	3.9	10098	10537	4.3	10356	10701	3.3
	Shop-keeping	4520	4622	2.3	4613	4672	1.3	4400	4463	1.4
	Others	7854	9458	20.4	8377	9271	10.7	8212	8923	8.7
Total non-farm income		38309	42182	10.1	38735	41805	7.9	38580	40659	5.4
Total income		120570	132127	9.6	121169	130320	7.6	122073	129485	6.1

It is apparent that average annual farm income of focal, proximal and control farmers was increased by 9.3, 7.4 and 6.4 percent, respectively; and average annual non-farm income increased by 10.1, 7.9 and 5.4 percent, respectively. Overall, average annual income of focal, proximal and control farmers was increased by 9.6, 7.6 and 6.1 percent, respectively (Table V). The results imply that while farmers earned Tk. 100 money income before practicing conservation agriculture, focal, proximal and control farmers earned about Tk. 110, Tk. 108 and Tk. 106 money income, respectively after practicing conservation agriculture. Farmers adopting conservation agriculture practice could save more time and money to invest in other income generating activities which ultimately resulted in more money income in comparison to proximal and control farmers.

Table VI represents the results of DID analysis for average annual income of the farmers. It is seen that within focal and proximal farmers, the DID estimated value of average annual farm income, non-farm income and total income was Tk. 1603, Tk. 803 and Tk. 3310, respectively; within focal and control farmers, it was Tk. 2351, Tk. 1794 and Tk. 4145, respectively; and within proximal and control farmers, it was Tk. 748, Tk. 991 and Tk. 1778, respectively. In most of the cases, a positive and statistically significant change is occurred which brings an indication that adoption of conservation agriculture practice had a significant impact on average annual income of the farmers in the study areas. The result is slightly supported by [28] where the authors identified significant economic benefits in terms of income and wealth generation from a variety of conservation agriculture practices.

F. Multidimensional Poverty Index (MPI)

To calculate multidimensional poverty index (MPI), poverty situation and livelihood condition of the farm households are evaluated on the basis of three poverty dimensions: health (weighted indicators: nutrition and child mortality), education (weighted indicators: years of schooling and child enrolment) and living standards (weighted indicators: cooking fuel, sanitation, water, electricity, floor and assets).

The proportion of deprived focal, proximal and control households was 20.8, 40.5 and 44.6 percent, respectively; and the proportion of privileged focal, proximal and control households was 79.2, 59.5 and 55.4 percent, respectively (Table VII). The households were deprived or privileged based on all the indicators of a single dimension or at a combination of the indicators across dimensions. The reason for a better livelihood condition of focal farmers by practicing conservation agriculture was that farmers employed their saved labour in other works and earned extra money income.

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Also, money saved from reduced use of synthetic fertilizers and pesticides were used in other livelihood activities. Crops free of synthetic fertilizers and pesticides as well as organic crops had a huge demand in the market and accordingly the farmers earned a notable amount of money by selling these products. This result is quite similar with [29] where the authors found that conservation agriculture practice extended the range of livelihood on a limited scale through improved yields and income.

G.Farmers' Perceptions Regarding Improvement in Soil Environmental Quality

To appraise the impact of adopting conservation agriculture on soil environmental quality, the researchers made discussion with the farmers of the study areas before and after adopting such farming practice. Following the discussion, ten (10) opinions were selected for this research. Each farmer was asked to indicate his/her opinion regarding the level of improvement. The number of farmers sharing their opinions on the selected statements and their percentages are represented in Table VIII. It is revealed that majority of both focal and proximal farmers stated about improved soil environmental condition after adopting conservation agriculture than before, while majority of control farmers mentioned the constant soil environmental condition in this regard.

It is seen from Table VIII that after adopting conservation agriculture, most of the focal farmers experienced increase in soil environmental quality (i.e., organic matter content, nutrient availability, water holding capacity, fertility, etc.). A healthy proportion of proximal farmers also faced improved condition but in case of control farmers, majority of them opined about constant state of soil environmental quality and decreased condition in some cases.

TABLE VI
ESTIMATION OF DID ANALYSIS TO EVALUATE IMPACT ON FARMERS' AVERAGE ANNUAL INCOME

Particulars		Farmers' categories		Difference
For focal and proximal farmers				
		Focal	Proximal	
Farm income	Before (Tk.)	82261	82434	-173
	After (Tk.)	89945	88515	1430
	Difference (Tk.)	7684	6081	1603*** (0.0072)[a]
Non-farm income	Before (Tk.)	38309	38735	-426
	After (Tk.)	42182	41805	377
	Difference (Tk.)	3873	3070	803 (0.1347)[a]
Total income	Before (Tk.)	120570	122073	-1503
	After (Tk.)	132127	130320	1807
	Difference (Tk.)	11557	8247	3310* (0.0849)[a]
For focal and control farmers				
		Focal	Control	
Farm income	Before (Tk.)	82261	83493	-1232
	After (Tk.)	89945	88826	1119
	Difference (Tk.)	7684	5333	2351 (0.1457)[a]
Non-farm income	Before (Tk.)	38309	38580	-271
	After (Tk.)	42182	40659	1523
	Difference (Tk.)	3873	2079	1794* (0.0953)[a]
Total income	Before (Tk.)	120570	122073	-1503
	After (Tk.)	132127	129485	2642
	Difference (Tk.)	11557	7412	4145*** (0.0014)[a]
For proximal and control farmers				
		Proximal	Control	
Farm income	Before (Tk.)	82434	83493	-1059
	After (Tk.)	88515	88826	-311
	Difference (Tk.)	6081	5333	748 (0.2654)[a]
Non-farm income	Before (Tk.)	38735	38580	155
	After (Tk.)	41805	40659	1146
	Difference (Tk.)	3070	2079	991 (0.1378)[a]
Total income	Before (Tk.)	121169	122112	-943
	After (Tk.)	130320	129485	835
	Difference (Tk.)	9151	7373	1778* (0.0591)[a]

[a]P-value; ***significant at 1% probability level; and *significant at 10% percent probability level.

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This result is partly similar with [30] where the authors overviewed on conservation agriculture and ecosystem services, and revealed that conservation agriculture changes soil properties and processes which can affect the delivery of ecosystem services, including climate regulation through carbon sequestration and greenhouse gas emissions, and regulation and provision of water through soil physical, chemical and biological properties.

TABLE VII
MULTIDIMENSIONAL POVERTY INDEX (MPI) TO MEASURE THE POVERTY INTENSITY

Indicators	Households' categories: Focal (N = 50)		Proximal (N = 150)		Control (N = 250)		Weights
	No. of households deprived (√) or privileged (×) based on the indicators						
	√	×	√	×	√	×	
Education							
No one has completed five years of schooling	19/50	31/50	121/150	29/150	154/250	96/250	1/6
At least one school-age child not enrolled in school	2/50	48/50	59/150	91/150	139/250	111/250	1/6
Health							
At least one member is malnourished	2/50	48/50	44/150	106/150	116/250	134/250	1/6
One or more children have been died	0/50	50/50	0/150	150/150	0/250	250/250	1/6
Living standards							
No electricity	4/50	46/50	38/150	112/150	93/250	157/250	1/18
No access to clean drinking water	0/50	50/50	0/150	150/150	0/250	250/250	1/18
No access to adequate sanitation	12/50	38/50	44/150	106/150	78/250	172/250	1/18
House having dirty floor	2/50	48/50	39/150	111/150	108/250	142/250	1/18
Household uses dirty cooking fuel (i.e., cowdung, firewood or charcoal)	50/50	0/50	150/150	0/150	250/250	0/250	1/18
Household has no car and owns at best one bicycle, motorcycle, radio, refrigerator, mobile or television	50/50	0/50	150/150	0/150	250/250	0/250	1/18
Score of the households[a]	0.208	0.792	0.405	0.595	0.446	0.554	-
Intensity of poverty (%): Deprived (√) households	20.8		40.5		44.6		-
Intensity of poverty (%): Privileged (×) households	79.2		59.5		55.4		-

[a]Score of deprived focal households = (19/50 × 1/6) + (2/50 × 1/6) + (2/50 × 1/6) + (0/50 × 1/6) + (4/50 × 1/18) + (0/50 × 1/18) + (12/50 × 1/18) + (2/50 × 1/18) + (50/50 × 1/18) + (50/50 × 1/18) = 0.208; score of privileged focal households = (31/50 × 1/6) + (48/50 × 1/6) + (48/50 × 1/6) + (50/50 × 1/6) + (46/50 × 1/18) + (50/50 × 1/18) + (38/50 × 1/18) + (48/50 × 1/18) + (0/50 × 1/18) + (0/50 × 1/18) = 0.792; scores of deprived or privileged households of proximal and control groups are calculated accordingly; percentage of deprived focal households = 0.208 × 100 = 20.8; percentage of privileged focal households = 0.792 × 100 = 79.2; and percentage of deprived or privileged households of proximal and control groups are calculated accordingly.

TABLE VIII
FARMERS' PERCEPTIONS ABOUT IMPROVEMENT IN SOIL ENVIRONMENTAL QUALITY

Statements	Farmers' categories: Focal (N = 50)			Proximal (N = 150)			Control (N = 250)		
	Increase	Decrease	Constant	Increase	Decrease	Constant	Increase	Decrease	Constant
Soil organic matter content	37 (74.0)[a]	3 (6.0)[a]	10 (20.0)[a]	69 (46.0)[a]	53 (35.3)[a]	28 (18.7)[a]	45 (18.0)[a]	69 (27.6)[a]	136 (54.4)[a]
Soil water holding capacity	31 (62.0)[a]	6 (12.0)[a]	13 (26.0)[a]	72 (48.0)[a]	18 (12.0)[a]	60 (40.0)[a]	62 (24.8)[a]	86 (34.4)[a]	102 (40.8)[a]
Soil fertility	29 (58.0)[a]	8 (16.0)[a]	13 (26.0)[a]	62 (41.3)[a]	40 (26.7)[a]	48 (32.0)[a]	30 (12.0)[a]	124 (49.6)[a]	96 (38.4)[a]
Soil nutrient availability	33 (66.0)[a]	3 (6.0)[a]	14 (28.0)[a]	65 (43.3)[a]	37 (24.7)[a]	48 (32.0)[a]	72 (28.8)[a]	117 (46.8)[a]	61 (24.4)[a]
Soil sediment content	28 (56.0)[a]	6 (12.0)[a]	16 (32.0)[a]	80 (53.3)[a]	21 (14.0)[a]	49 (32.7)[a]	32 (12.8)[a]	42 (16.8)[a]	176 (70.4)[a]
Soil compaction	39 (78.0)[a]	2 (4.0)[a]	9 (18.0)[a]	61 (40.7)[a]	58 (38.7)[a]	31 (20.7)[a]	73 (29.2)[a]	136 (54.4)[a]	41 (16.4)[a]
Soil erosion	4 (8.0)[a]	26 (52.0)[a]	20 (40.0)[a]	50 (33.3)[a]	34 (22.7)[a]	66 (44.0)[a]	66 (26.4)[a]	85 (34.0)[a]	99 (39.6)[a]
Quality of nearby water resources	32 (64.0)[a]	5 (10.0)[a]	13 (26.0)[a]	51 (34.0)[a]	63 (42.0)[a]	36 (24.0)[a]	12 (4.8)[a]	97 (38.8)[a]	141 (56.4)[a]
Air quality	29 (58.0)[a]	9 (18.0)[a]	12 (24.0)[a]	52 (34.7)[a]	57 (38.0)[a]	41 (27.3)[a]	72 (28.8)[a]	86 (34.4)[a]	92 (36.8)[a]
Biodiversity of agrarian medium	28 (56.0)[a]	10 (20.0)[a]	12 (24.0)[a]	64 (42.7)[a]	33 (22.0)[a]	53 (35.3)[a]	52 (20.8)[a]	149 (59.6)[a]	49 (19.6)[a]
Average perception on environmental quality	29 (58.0)[a]	8 (16.0)[a]	13 (26.0)[a]	63 (42.0)[a]	41 (27.3)[a]	46 (30.7)[a]	51 (20.4)[a]	98 (39.2)[a]	99 (39.6)[a]

[a]Percentages of farmers.

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H. Factors Influencing Improvement in Soil Environmental Quality

A probit model was used bringing the determinants influencing improvement in soil environmental quality under conservation agriculture practice. (9) represents six explanatory variables which were identified as major factors for the estimated probit model.

$$Z_i = 0.284 + 1.140Q_1 + 0.011Q_2 - 0.043Q_3 + 0.001Q_4 + 0.001Q_5 - 0.002Q_6 \quad (9)$$

Three out of six explanatory variables included in the model were found significant in explaining the variation in improving soil environmental quality. These variables were minimum soil tillage operation, permanent organic soil cover, and application of compost and vermicompost (Table IX).

TABLE IX
ESTIMATES OF PROBIT MODEL OF FACTORS INFLUENCING IMPROVEMENT IN SOIL ENVIRONMENTAL QUALITY

Variables	Coefficient (β)	Standard Error	z	P>|z|	95% confidence interval	
Constant	0.284	0.850	0.33	0.284	-0.184	2.758
Minimum tillage operation (Q_1)	1.140	0.841	1.36	0.039	-0.032	-0.009
Permanent organic soil cover (Q_2)	0.011**	0.349	0.41	0.068	-0.080	-0.029
Diversified crop rotation (Q_3)	-0.043	0.016	-0.75	0.127	-0.025	0.389
Application of cowdung and bioslurry (Q_4)	0.001*	0.039	1.09	0.230	0.004	-0.001
Application of compost and vermicompost (Q_5)	0.001**	0.001	1.01	0.043	0.001	0.005
Implementation of IPM technology (Q_6)	-0.002	0.001	-1.25	0.129	-0.003	0.000

**Significant at 5% probability level; and *significant at 10% probability level.

Marginal effect was computed differently for discrete (i.e., categorical) and continuous variables. Marginal effect measured discrete change i.e., how predicted probabilities were changed due to change in binary independent variable from 0 to 1. Marginal effects for continuous variables measured the instantaneous rate of change (Table X).

The result of marginal effect shows that minimum tillage operation had a positive value of dZ/dQ and it was 0.128. It indicated that the probability of improving soil environmental quality is 0.128 times higher for practicing minimum-till farming compared to for not practicing it (Table X).

Permanent organic soil cover (i.e., crop residue) had a positive value of dZ/dQ which was 0.015 and statistically significant at 5% probability level. It meant that for keeping crop residue in the crop field, the probability of improvement in soil environmental quality is 0.015 times higher than without keeping crop residue. This reason was that keeping crop residue in the field helped to manage soil nutrient balance or re-cycling and it reduces emission of soil particulars. The result of marginal effect shows following diversified crop rotation had a negative value of dZ/dQ and it was 0.001. It implied that if crop rotation is increased by 1 unit, the probability of improving soil environmental quality will decrease by 0.001 times (Table X).

TABLE X
ESTIMATES OF MARGINAL EFFECT OF FACTORS INFLUENCING IMPROVEMENT IN SOIL ENVIRONMENTAL QUALITY

Variables	dZ/dQ	Standard Error	z	P>|z|	95% confidence interval		Q
Minimum tillage operation (Q_1)	0.128	0.068	1.88	0.239	-0.012	-0.003	0.478
Permanent organic soil cover (Q_2)	0.015**	0.037	0.41	0.048	-0.030	-0.011	0.338
Diversified crop rotation (Q_3)	-0.001	0.002	-0.75	0.352	0.010	0.147	2.318
Application of cowdung and bioslurry (Q_4)	0.005*	0.005	1.05	0.073	-0.001	-0.000	19.034
Application of compost and vermicompost (Q_5)	0.001**	0.000	0.95	0.029	0.000	0.002	25.115
Implementation of IPM technology (Q_6)	-0.001	0.000	-1.22	0.264	-0.001	0.000	3.331

**Significant at 5% probability level; and *significant at 10% probability level.

The result of marginal effect shows that application of cowdung and bioslurry had a positive value of dZ/dQ and it was 0.005, which was statistically significant at 10% level of probability. It indicated that if cowdung and bioslurry application is increased by 1 unit, the probability of improvement in soil environmental quality will increase by 0.005 times. The reason was that applying cowdung and bioslurry in the field helped to provide soil nutrient and improve soil health. Application of compost and vermicompost had a positive value of dZ/dQ which was 0.001 and it was statistically significant at 5% level of probability. It demonstrated that if compost and vermicompost application is increased by 1 unit, the probability of improving soil environmental quality will increase by 0.001 times. The reason was that application of compost and vermicompost is very favourable to increase soil aeration, water infiltration, nitrogen availability to the plants and the microbial activity of the soil. Implementation of IPM technology for pest control had a negative value of dZ/dQ and it was 0.001. It implied that if the implementation of IPM technology is increased by 1 unit, the probability of improving soil environmental quality will decrease by 0.001 times (Table X).

V. CONCLUSION AND RECOMMENDATION

The study concludes that conservation agriculture, as a new resource saving farming practice was appreciated and successfully adopted by the farmers. The study exposed that crop productivity of the farmers adopting conservation agriculture practice increased in response to the crop production in the entire region. It is also revealed that farmers' income was increased through adopting conservation agriculture. Farmers got higher price for their product free from fatal medicine and synthetic fertilizers. This practice helped the farmers to minimize their labour and other input cost. The study also indicates that poverty in terms of deprivation of health, education and living standards was decreased; and overall socioeconomic condition was improved after adopting conservation agriculture practice. Majority of both focal and proximal farmers avowed about enhanced soil environmental circumstances after adopting conservation agriculture than before, while majority of control farmers stated about constant soil environmental condition. A number of factors had significant influence on improving environmental quality due to practicing conservation agriculture. Government input support and agricultural extension services should be properly executed and monitored to promote the practice of conservation agriculture. Also, programmes for motivating and training the farmers should be arranged by different government and non-government organizations to enhance farmers' knowledge on conservation agriculture practice.

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