Original Research Paper

Improving Farmers' Income and Soil Environmental Quality through Conservation Agriculture Practice in Bangladesh

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Abstract: The study was accomplished for assessing conservation agriculture practice's impact on farmers' income and soil environmental quality in Bangladesh. Majority of the farmers were within the late majority group in terms of adopting this farming practice. Average annual agricultural income of focal farmers was increased at a higher rate compared to proximal and control farmers after adopting this practice. Most of the focal and proximal farmers stated about improved soil environmental condition where majority of control farmers stated about constant soil environmental condition in this regard. Minimum tillage operation, permanent organic soil cover and application of compost and vermicompost were found significant factors under conservation agriculture affecting soil environmental quality. The problems faced by the farmers included high price of inputs, lack of institutional credit, lack of knowledge about conservation agriculture, etc. Input support, incentive, training programmes and extension services should be well executed by different government and non-government organizations for building consciousness and enhance the knowledge of the farmers on conservation agriculture practice.

Keywords: Farmers' Income, Soil Environmental Quality, Conservation Agriculture, Bangladesh

Introduction

The economy of Bangladesh is mostly dependent on agriculture where above 80% farmers are smallholder with less than 1.0 hectare cultivable land. The rural economy comprises a noteworthy component of the national GDP with agriculture accounting for 17.2% (BBS, 2014). As a result of 'Green Revolution', Bangladesh had achieved self adequacy in food production for a shorter period, but long run use of synthetic fertilizers and pesticides resulted in diminished soil fertility and productivity (Kafiluddin and Islam, 2008). In this context, conservation agriculture is fetching increasingly essential in overcoming the problems of waning agricultural productivity in a developing country like Bangladesh. Conservation agriculture can be defined as a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment by following the principles of minimum tillage operation, crop residue management and diversified crop rotations (FAO, 2007). About 8-10% farmers around the world follow this practice although it aspires to help the farmers in earning more money income with reduced amount of lab our, irrigation and other input costs; remain land healthy and productive; and protect natural environment (Lampkin and Padel, 1994; Parrott *et al*., 2006; Willer *et al*., 2008).

Environmental problems caused by conventional agricultural practice mainly incorporate infectivity of water and carbon-di-oxide (CO_2) loss induced from tillage. Practicing conservation agriculture assists agricultural ecosystem to help control agricultural pests; maintain biodiversity; maintain soil fertility; stabilize climatic condition; purify water and air; and normalize disease hauling organisms. Soil, containing high amount of carbon amid organic soil cover and crop residues on the shell are very effectual to boost soil organic content that allows a buffering capacity on soil temperature and improve soil structure and hydraulic conductivity (Reicosky, 2001; West, 2004). Conservation agriculture practice can offset carbon emission through land use and incineration of fossil fuel. This practice is a win-win condition where agriculture wins with better

production of food and fiber and society wins with the enhanced environmental eminence. Cover crops help to bind the soil elements into aggregates and salvage soil nutrient content that influence the biological community in the soil. Earthworms can increase water penetration, nitrogen availability to plants, soil ventilation and the microbial activity of the soil by feeding off the putrefying fungi, protozoa and bacteria that combine small soil specks altogether into larger aggregates (Clapperton, 2003).

Importance of such farming practice has been portrayed in a good number of literatures. A reticent effort has been made here to appraise the previous research studies which are: Mine *et al.* (2014) conducted a research on adoption of conservation agriculture in Iowa, Mexico focusing on cover crop use, crop rotations and reduced tillage that can afford many soil conservation benefits and their prospective to contest erosion and nutrient loss and declared them an important tool for protecting water quality. Nguema *et al.* (2013) studied on conservation agriculture practice's farm-level economic impacts in Ecuador and stated that particular cover crops, crop rotations and reduced amount of tillage intended to reduce soil erosion and increase soil organic matter that can escort to increased farm household income. Lai *et al.* (2012) accomplished a comparative economic and gender, labor analysis of conservation agriculture in tribal villages inside India and exposed that legume alternation without minimum tillage was more profitable than legume alternation with minimum tillage and it was comparatively more profitable than traditional agriculture. Mazvimavi *et al.* (2012) executed an analysis on maize productivity and efficiency practicing conservation agriculture in Zimbabwe and showed that 39% additional output was produced by the farmers following conservation agriculture practice in comparison with conventional agriculture practice. Aune (2012) reviewed the environmental impact of traditional, organic and conservation agriculture and showed that in building soil organic matter with less nitrogen and greenhouse gas emission, conservation agriculture was more efficient than organic farming and conventional agriculture. Jat *et al.* (2011) discussed the nutrient management perspectives of conservation agriculture in South Asian cereal systems and illustrated that nutrient use, total food grain production and average yield had been increased by 1573%, 145% with an increase in area of just 3.5 and 125%, respectively in India in the last five decades. Roy *et al.* (2004) focused on conservation tillage's status for small farming in Bangladesh using power tiller operated seeder, zero-till drill with fertilizer distributor and bed former and indicated that these resource conserving technologies had been proved appropriate in many areas of the country.

The above mentioned literatures evidently indicate that most of the studies dealt with conservation agriculture and its economic or environmental aspects but these are not preferably related to the context of Bangladesh. In light of this situation, to curtail the research gap, this study would be supportive at evaluating the consequences of practicing conservation agriculture on farmers' crop profitability as well as their farm income considering soil environmental issues in the circumstance of Bangladesh. The study will identify the determinants of conservation agriculture practice that have significant influence on soil environmental quality. Moreover, the study will address the problems faced by the farmers in practicing conservation agriculture. The specific study objectives are: (i) To assess the impact of conservation agriculture practice on farmers' income and soil environmental quality in relation to conventional agriculture practice; and (ii) to identify the problems faced by the farmers in practicing conservation agriculture.

Materials and Methods

Selection of the Study Areas

Five agro-ecological zones of Bangladesh namely Mymensingh (major crop: potato), Bogra (major crop: bean), Tangail (major crop: pineapple), Sherpur (major crop: rice) and Jamalpur (major crop: wheat) were selected to conduct the study.

Selection of Sample and Sampling Technique

For investigation, three categories of farmers were targeted: focal farmers (farmers who were receiving technical and logistic support from the project and having regular extension contact), proximal farmers (farmers neighboring to focal farmers, receiving technical advice and having occasional extension contact) and control farmers (farmers receiving no training, technical support and extension contact). Following purposive sampling technique, 10 focal farmers and following random sampling technique, 20 proximal and 30 control farmers (i.e., a total of 60 farmers) were selected from each of the study areas. Thus, a total of 300 farmers were included in the study.

Data Sources and Acquisition Methods

Questionnaire survey, Focus Group Discussion (FGD) and Key Informant Interview (KII) were performed for collecting the primary data. Secondary data sources like reports, publications, handouts, etc. relevant with this study were also checked.

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. 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, the following simple percentage formula was used:

$$PPI = \begin{bmatrix} No.\ of\ respondents'\ opinion\ about\ statements \\ (increase,\ decrease\ or\ constant) \times 100 \end{bmatrix} \quad (1)$$

$\div Total\ no.\ of\ respondents$

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. The following probit model was used to document the factors' influence level determining soil environmental quality:

$$Z_i = \Phi^{-1}(P_i) = \beta_0 + \beta_1 Q_1 + \beta_2 Q_2 \\ + \beta_3 Q_3 + \beta_4 Q_4 + \beta_5 Q_5 + \beta_6 Q_6 + U_i \quad (2)$$

Where:
Φ = Cumulative distribution function of an explanatory variable $\left[F(Q) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\beta_0 + \beta_i Q_i} e^{\frac{-Z^2}{2}} dZ \right]$ that follows normal distribution with mean μ and variance σ^2
P_i = The probability of improving environmental condition or not
$P_i = 1$ = Indicates improved condition and $P_i = 0$ indicates otherwise

Dependent variable:

Z_i = Improvement in soil environmental quality

Independent variables:

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
U_i = Disturbance term

The marginal probabilities of the key determinants of improving soil environmental quality were calculated on the basis of the figures derived from the marginal effect of the probit model was as follows:

$$dZ / dQ = \beta_i \varphi \left[\Phi^{-1}(P_i) \right] \quad (3)$$

Where:
β_i = Estimated probit regression coefficient with respect to the ith factor
φ = Standard normal probability distribution function $\left[f(Q) = \frac{1}{\sqrt{2\pi}} e^{\frac{-Z^2}{2}} \right]$
Φ = Standard normal cumulative distribution function
P_i = Estimated probability of soil environmental quality improvement

Problem Confrontation Index (PCI)

The researcher identified the major problems faced by the farmers in practicing conservation agriculture. An overall score of the problems faced by focal, proximal and control farmers were computed by adding their scores of the problems in all 13 selected problems. Each farmer was asked to indicate the extent of difficulty caused by each of the problems by checking any of the four responses such as 'frequently', 'occasionally', 'rarely' and 'not at all' and weights were assigned to these responses as 3, 2, 1 and 0, respectively. The scores of Problem Confrontation Index (PCI) for each selected problem were computed through using the subsequent formula:

$$PCI = \left(P_{frequently} \times 3 \right) + \left(P_{occasionally} \times 2 \right) \\ + \left(P_{rarely} \times 1 \right) + \left(P_{not\ at\ all} \times 0 \right) \quad (4)$$

Where:
$P_{frequently}$ = Number of responses indicating the problem occurred frequently
$P_{occasionally}$ = Number of responses indicating the problem occurred occasionally
P_{rarely} = Number of responses indicating the problem occurred rarely
$P_{not\ at\ all}$ = Number of responses indicating no problem at all

The problems were ranked according their PCI score which denoted their severity in practicing conservation agriculture.

Results and Discussion

Socioeconomic Characteristics of the Selected Farmers

The basic information of the farmers is represented in Table 1. It is seen that focal, proximal and control farmers' average household size and average farm size were 5.0, 5.0 and 6.0; and 0.48, 0.41 and 0.52, respectively. Focal farmers' average dependency ratio (1.4) was relatively lower than proximal and control farmers (1.7 and 3.0, respectively) indicating focal farmers as more self-employed. The percentages of male and female respondents in case of focal, proximal and control farmers were 68.0, 70 and 69.2; and 32.0, 30 and 30.8, respectively.

Average age of focal, proximal and control farmers was 34, 37 and 36 years, respectively. 42.0% focal farmers could put sign only, but 56.0 and 55.6% proximal and control farmers, respectively were illiterate in the study areas. Most of the farmers were engaged in farm (i.e., agriculture) as well as non-farm (i.e., labour selling, service, small business, etc.) income generating activities (76.0, 72.0 and 70.8% focal, proximal and control farmers, respectively). It is also found that the higher portion of the farmers in the study areas were commercial farmers (82.0% focal, 71.0% proximal and 79.0% control farmers, respectively) (Table 2).

Nature of Adopting Conservation Agriculture Practice

Table 2 shows farmers' nature of adoption of conservation agriculture practice. In the research areas, the farmers of all categories were completely reliant on usage of synthetic fertilizers, pesticides and medicines before adopting conservation agriculture. Focal farmers pursued the fundamental principles of conservation agriculture after adopting conservation agriculture. On the contrary, proximal farmers tried to observe and follow the farming practices of focal farmers, but no conservation agriculture principle was followed by control farmers, rather they continued practicing traditional crop farming. It is experienced that the principles of practicing zero/minimum tillage and retaining crop residue were adopted by focal farmers fully. The selection of apposite crop rotation being an extensive process, it was adopted by them partially. Complete prohibition of using synthetic fertilizers was not possible, but the full usage of organic fertilizers like compost, vermicompost, cowdung and bioslurry and IPM technology; and no usage of pesticides, herbicides and medicines were guaranteed. Retention of crop residue and usage of compost, cowdung and bioslurry were fully adopted by proximal farmers. They also adopted partial use of fertilizers, pesticides and herbicides. Alternatively, no control farmer followed practicing zero/minimum tillage, retaining crop residue and practicing diversified crop rotation. They remained persistent with full usage of chemical fertilizers, pesticides, herbicides and medicines; and partial usage of cowdung and bioslurry (Table 2).

Adopter Categories

Rogers (1995) 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 namely, innovators, early adopters, early majority, late majority and laggards in order to standardize the usage of adopter categories in diffusion research. It is evident from Table 3 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.

Turnover from Crop Production

Turnover from crop farming was measured in terms of gross return, net return and marginal rate of return from individual farmer's perspective. Variable and fixed costs were taken into deliberation to estimate the total cost of production. The variable costs included human labour, power tiller, seeds/seedlings, fertilizers, pesticides, medicine, irrigation and fencing; and fixed cost included lease value of land and interest on operating capital. The following formulas were used for calculation:

$$Gross\ return\ (GR) = Y_{fp} \times P_{fp} \tag{5}$$

Where:
Y_{fp} = Yield of final product per unit area
P_{fp} = Price of final product

$$Net\ return\ (NR) = GR - GC \tag{6}$$

Where:
GR = Gross return
GC = Gross cost

$$Marginal\ rate\ of\ return\ (MRR) = MR \div MC \tag{7}$$

Where:
MR = Marginal return (i.e., $GR \div Y_{fp}$)
MC = Marginal cost (i.e., $GC \div Y_{fp}$)

It is evident from Table 4 that total cost incurred by focal, proximal and control farmers was Tk.

156104, Tk. 155834 and Tk. 156796 per ha, respectively before adopting conservation agriculture which was decreased to Tk. 124834, Tk. 142766 and Tk. 155783 per ha, respectively after adopting conservation agriculture practice. Total cost was decreased by 20.0, 8.4 and 0.6% for focal, proximal and control farmers, respectively. Though gross return of focal farmers was decreased by 0.6% (from Tk. 323743 to Tk. 321866) after adopting conservation agriculture; it was increased in case of proximal and control farmers by 6.5 and 10.3%, respectively (from Tk. 300698 to Tk. 320360; and from Tk. 307613 to Tk. 339279, respectively).

Net return of focal, proximal and control farmers was Tk. 167638, Tk. 144864 and Tk. 150817, respectively before adopting conservation agriculture practice; and it was increased to Tk. 197032, Tk. 177594 and Tk. 183496, respectively after adopting conservation agriculture indicating an increase in net return by 17.5, 22.6 and 21.7%, respectively.

Table 1. Basic information about the selected farmers (in average)

Particulars		Farmers' categories		
		Focal	Proximal	Control
Household size (no.)		5.00	5.00	6.00
Farm size (ha)		0.48	0.41	0.52
Dependency ratio (no.)		1.40	1.70	3.00
Sex distribution (% of farmers)	Male	68.0	70.0	69.2
	Female	32.0	30.0	30.8
Age (years)		34.0	37.0	36.0
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	Subsistence	18.0	29.0	21.0
(% of farmers)	Commercial	82.0	71.0	79.0

Table 2. Farmers' nature of adoption of conservation agriculture practice

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

a. √ indicates full adoption
b. ₪ indicates partial adoption
c. × indicates no adoption.

Table 3. Trend of adopting conservation agriculture practice by the farmers

Adopter categories	Trend of adoption	
	No. of farmers (N[a] = 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. N indicates number of farmers

Table 4. Turnover from crop production in the study areas

| | Farmers' categories | | | | | |
| | Focal | | Proximal | | Control | |
Particulars	Before	After	Before	After	Before	After
Total output (quintal/ha)	141.5	142.2	140.3	141.8	140.3	142.2
Price (Tk./quintal)	2288	2263	2143	2259	2193	2386
Total cost (TC) (Tk./ha)	156104	124834	155834	142766	156796	155783
Change in TC (%)	-20.0		-8.4		-0.6	
Gross return (GR) (Tk./ha)	323743	321866	300698	320360	307613	339279
Change in GR (%)	-0.6		6.5		10.3	
Net return (NR) (Tk./ha)	167638	197032	144864	177594	150817	183496
Change in NR (%)	17.5		22.6		21.7	
Marginal cost (Tk./quintal)	1103	878	1111	1007	1118	1096
Marginal return (Tk./quintal)	2288	2263	2143	2259	2193	2386
Marginal rate of return (MRR)	2.07	2.58	1.93	2.24	1.96	2.18
Change in MRR (%)	24.3		16.3		11.0	

Table 5. Average annual agricultural income of the farmers

| | Farmers' categories | | | | | | | | |
| | Focal | | | Proximal | | | Control | | |
Sources of income	Before (Tk.)	After (Tk.)	Change (%)	Before (Tk.)	After (Tk.)	Change (%)	Before (Tk.)	After (Tk.)	Change (%)
Rice	27985	30279	8.2	28295	30138	6.5	28855	30127	4.4
Vegetables	33267	36754	10.5	32664	34519	5.7	32419	34972	7.9
Fruits	8617	9099	5.6	8801	9100	3.4	8325	8514	2.3
Agroforestry	1549	1970	27.2	1805	1946	7.8	2000	2045	2.3
Livestock	8037	9112	13.4	8779	9473	7.9	9027	9672	7.1
Fisheries	750	820	9.3	695	866	24.6	754	910	20.7
Others	1846	2065	11.9	1955	2459	25.8	1885	2249	19.3
Total	82051	90099	9.8	82994	88501	6.6	83265	88489	6.3

Table 6. Farmers' perceptions regarding the impact of conservation agriculture practice on soil environmental quality

| | Farmers' categories | | | | | | | | |
| | Focal (N = 50)[a] | | | Proximal (N = 100)[a] | | | Control (N = 150)[a] | | |
Statements	Increase	Decrease	Constant	Increase	Decrease	Constant	Increase	Decrease	Constant
Soil organic matter content	37 (74.0)[b]	3 (6.0)[b]	10 (20.0)[b]	36 (36.0)[b]	22 (22.0)[b]	42 (42.0)[b]	28 (18.7)[b]	53 (35.3)[b]	69 (46.0)[b]
Soil water holding capacity	31 (62.0)[b]	6 (12.0)[b]	13 (26.0)[b]	45 (45.0)[b]	25 (25.0)[b]	30 (30.0)[b]	60 (40.0)[b]	18 (12.0)[b]	72 (48.0)[b]
Soil fertility	29 (58.0)[b]	8 (16.0)[b]	13 (26.0)[b]	38 (38.0)[b]	20 (20.0)[b]	42 (42.0)[b]	48 (32.0)[b]	40 (26.7)[b]	62 (41.3)[b]
Soil nutrient availability	33 (66.0)[b]	3 (6.0)[b]	14 (28.0)[b]	49 (49.0)[b]	25 (25.0)[b]	26 (26.0)[b]	48 (32.0)[b]	37 (24.7)[b]	65 (43.3)[b]
Soil sediment content	28 (56.0)[b]	6 (12.0)[b]	16 (32.0)[b]	36 (36.0)[b]	38 (38.0)[b]	26 (26.0)[b]	49 (32.7)[b]	21 (14.0)[b]	80 (53.3)[b]
Soil compaction	39 (78.0)[b]	2 (4.0)[b]	9 (18.0)[b]	51 (51.0)[b]	16 (16.0)[b]	33 (33.0)[b]	31 (20.7)[b]	58 (38.7)[b]	61 (40.7)[b]
Soil erosion	4 (8.0)[b]	26 (52.0)[b]	20 (40.0)[b]	13 (13.0)[b]	45 (45.0)[b]	42 (42.0)[b]	66 (44.0)[b]	34 (22.7)[b]	50 (33.3)[b]
Quality of nearby water resources	32 (64.0)[b]	5 (10.0)[b]	13 (26.0)[b]	37 (37.0)[b]	35 (35.0)[b]	28 (28.0)[b]	36 (24.0)[b]	63 (42.0)[b]	51 (34.0)[b]
Air quality	29 (58.0)[b]	9 (18.0)[b]	12 (24.0)[b]	40 (40.0)[b]	32 (32.0)[b]	28 (28.0)[b]	41 (27.3)[b]	57 (38.0)[b]	52 (34.7)[b]
Biodiversity of agrarian medium	28 (56.0)[b]	10 (20.0)[b]	12 (24.0)[b]	53 (53.0)[b]	28 (28.0)[b]	19 (19.0)[b]	53 (35.3)[b]	33 (22.0)[b]	64 (42.7)[b]
Average perception on soil environmental quality	29 (58.0)[b]	8 (16.0)[b]	13 (26.0)[b]	40 (40.0)[b]	28 (28.0)[b]	32 (32.0)[b]	46 (30.7)[b]	41 (27.3)[b]	63 (42.0)[b]

a. N indicates number of farmers; and
b. Figures within parentheses indicate percentages of farmers.

Table 4 also depicts that after adopting conservation agriculture practice, marginal rate of return of focal, proximal and control farmers was increased to 2.58, 2.24 and 2.18 from 2.07, 1.93 and 1.96 by 24.3, 16.3 and 11.0%, respectively. Low input employment cost and higher consumer magnetism to organic products were the major reasons of focal farmers' being more profitable compared to proximal and control farmers.

Average Annual Agricultural Income of the Sample Farmers

Table 5 represents the money income earned by the farmers in the study areas from different agricultural sources like crop (rice, vegetables, etc.), livestock (large animal i.e., cow, ox, bullock, buffalo, goat, sheep, etc.; and small animal i.e., poultry, duck, pigeon, etc.), fishery, agroforestry and others. It is apparent that average annual farm income of focal, proximal and control farmers was increased by 9.8, 6.6 and 6.3%, respectively. The results entail that farmers earned Tk. 100 money income from agricultural sources before practicing conservation agriculture while after practicing conservation agriculture, focal, proximal and control farmers earned about Tk. 110, Tk. 107 and Tk. 106 money income, respectively. This findings is faintly similar with the result of Uddin and Fatema (2016) where the authors found that management of rice crop residue had a significant impact on crop productivity, profitability and annual income of the farm households.

Farmers' Perceptions about Impact of Conservation Agriculture Practice on 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. After the discussion, ten (10) opinions were selected for the 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 6. 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 stated about constant soil environmental condition in this regard.

Table 6 depicts that after adopting conservation agriculture, focal farmers experienced increase in soil organic matter content (74.0%), soil water holding capacity (62.0%), soil fertility (58.0%), soil nutrient availability (66.0%), soil sediment content (56.0%), soil compaction (78.0%), quality of nearby water resources (64.0%), air quality (58.0%) and biodiversity of agrarian medium (56.0%); and decrease in soil erosion (52.0%).

According to proximal farmers, they experienced increase in soil water holding capacity (45.0%), soil nutrient availability (49.0%), soil compaction (51.0%), quality of nearby water resources (37.0%), air quality (40.0%) and biodiversity of agrarian medium (53.0%); but decrease in soil organic matter content (42.0%) and soil fertility (42.0%) with a constant state of soil sediment content (38.0%) and soil erosion (45.0%). On the other hand, 46.0, 48.0, 41.3, 43.3, 53.3, 40.7 and 42.7% control farmers observed no change in soil organic matter content, soil water holding capacity, soil fertility, soil nutrient availability, soil sediment content, soil compaction and biodiversity of agrarian medium, respectively; but they observed increased soil erosion (44.0%) and decreased quality of nearby water resources (42.0%) and air quality (38.0%) while practicing conventional farming system. Overall, 58.0, 16.0 and 26.0% focal farmers; 40.0, 28.0 and 32.0% proximal farmers; and 30.7.0, 27.3.0 and 42.0% control farmers in the study areas assured about increased, decreased and constant soil environmental quality, respectively after adopting conservation agriculture practice (Table 5). This result is partly similar with Palm *et al.* (2014) 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.

Factors Influencing Improvement in Soil Environmental Quality under Conservation Agriculture Practice

A probit model was used conveying the determinants influencing improvement in soil environmental quality under conservation agriculture practice. Six explanatory variables were identified as major factors for this study. 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 7).

Therefore the estimated equation was as follows:

$$Z_i = 1.286 + 0.011Q_1 + 0.026Q_2 \\ -0.182Q_3 + 0.002Q_4 + 0.003Q_5 - 0.002Q_6 \tag{8}$$

Marginal effect was calculated separately for categorical and continuous variables. It measured distinct change i.e., how expected probabilities were altered as the binary explanatory variable changed from 0 to 1. Marginal effects for continuous variables measured the instantaneous rate of change (Table 8).

Table 7. Estimates of probit model of factors influencing improvement in soil environmental quality

Variables	Coefficient (β)	Standard error	z	P>|z|	95% confidence interval	
Constant	1.286	0.751	1.71	0.387	-0.184	2.758
Minimum tillage operation (Q_1)	0.011	0.011	1.08	0.042	-0.032	-0.009
Permanent organic soil cover (Q_2)	0.026	0.278	0.91	0.047**[a]	-0.080	-0.029
Diversified crop rotation (Q_3)	-0.182	0.106	-1.73	0.384	-0.025	0.389
Application of cowdung and bioslurry (Q_4)	0.002	0.001	2.67	0.077*[b]	0.004	-0.001
Application of compost and vermicompost (Q_5)	0.003	0.001	2.48	0.093*[b]	0.001	0.005
Implementation of IPM technology (Q_6)	-0.002	0.001	-2.83	0.175	-0.003	0.000

a. ** indicates significant at 5% probability level
b. * indicates significant at 10% probability level

Table 8. 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)	0.004	0.004	1.08	0.213	-0.012	-0.003	38.240
Permanent organic soil cover (Q_2)	0.010	0.011	0.91	0.031**[a]	-0.030	-0.011	9.040
Diversified crop rotation (Q_3)	-0.069	0.040	-1.72	0.485	0.010	0.147	0.949
Application of cowdung and bioslurry (Q_4)	0.001	0.000	2.69	0.087*[b]	-0.001	-0.000	394.700
Application of compost and vermicompost (Q_5)	0.001	0.000	2.49	0.061*[b]	0.000	0.002	294.313
Implementation of IPM technology (Q_6)	-0.001	0.000	-2.85	0.114	-0.001	0.000	763.707

a. ** indicates significant at 5% probability level
b. * indicates significant at 10% probability level

The result of marginal effect shows that minimum tillage operation had a positive value of dZ/dQ and it was 0.004. It meant that the probability of improving soil environmental quality is 0.004 times higher for practicing minimum-till farming compared to for not practicing it (Table 8).

Keeping permanent organic soil cover (i.e., crop residue) had a positive value of dZ/dQ which was 0.010 and it was 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 0.010 times higher than for not keeping crop residue. This reason was that keeping crop residue in the field helped to manage soil nutrient balance or cycling it and reduce emission of soil particulars.

The result of marginal effect shows that following diversified crop rotation had a negative value of dZ/dQ and it was 0.069. It indicated that if crop rotation is increased by 1 unit, the probability of improving soil environmental quality will decrease by 0.069 times (Table 8).

The result of marginal effect shows that application of cowdung and bioslurry had a positive value of dZ/dQ and it was 0.001, which was statistically significant at 10% level of probability. It demonstrated that if cowdung and bioslurry application is increased by 1 unit, the probability of improvement in soil environmental quality will increase by 0.001 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 10% probability level. It

indicated 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 complimentary for amplifying water infiltration, soil aeration, soil microbial activity and nitrogen availability to the plants.

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.

Problem Confrontation Index (PCI)

Problem Confrontation Index (PCI) is a mathematically problem ranking index which is defined as a set of objects whose state must satisfy a number of problems or limitations. It represents the entities in a problem as a homogeneous collection of finite limitations over variables in a specific area. The farmers of the study areas were asked to give their opinion on 13 selected problems which were identified during data collection period and after computing the PCI scores, the problems were ranked according to their PCI score. The computed PCI score of the 13 problems ranged from 113 to 136 (against a possible range from 0 to 150) for focal farmers, 204 to 261 (against a possible range from 0 to 300) for proximal farmers and 314 to 388 (against a possible range from 0 to 300) for control farmers which were arranged in rank order according to their PCI scores as shown in Table 9.

Table 9. Problem confrontation index including thirteen (13) selected problems

Problems identified	Focal (N = 50)[a]						Proximal (N = 100)[a]						Control (N = 150)[a]					
	Frequently (3)	Occasionally (2)	Rarely (1)	Not at all (0)	PCI	Rank order	Frequently (3)	Occasionally (2)	Rarely (1)	Not at all (0)	PCI	Rank order	Frequently (3)	Occasionally (2)	Rarely (1)	Not at all (0)	PCI	Rank order
Lack of good quality inputs	33	6	5	6	116[b]	12	65	18	7	10	238[b]	10	96	31	14	9	364[b]	5
High price of inputs	41	5	3	1	136	1	71	20	4	5	257	3	110	19	18	3	386	3
Lack of transportation and storage facilities	38	4	6	2	128	8	59	17	20	4	231	11	85	21	17	27	314	13
Lack of knowledge on conservation agriculture	39	5	5	1	132	5	72	10	9	9	245	6	89	22	35	4	346	9
Less production due to minimum tillage	40	5	3	2	133	4	72	12	6	10	246	5	106	14	27	3	373	4
Weed infestation due to minimum tillage	35	9	4	2	127	9	69	11	13	7	242	7	90	16	24	20	326	12
Outbreak of diseases	36	10	2	2	130	6	53	16	16	15	207	12	88	23	21	18	331	11
Crop residues cannot be used as fuel	35	5	6	4	121	10	69	12	9	10	240	8	94	13	27	16	335	10
Crop residues cannot be used as animal feed	37	8	2	3	129	7	68	21	2	9	248	4	103	21	10	16	361	6
Crop rotation being a boring practice	42	3	2	3	134	3	71	20	8	1	261	1	109	25	11	5	388	1
Lack of extension service	31	7	6	6	113	13	57	11	11	21	204	13	99	22	16	13	357	7
Maintenance is difficult	34	6	3	7	117	11	66	10	21	3	239	9	93	28	21	8	356	8
Insufficient institutional credit	40	6	3	1	135	2	70	19	10	1	258	2	107	26	14	3	387	2

a. N indicates number of farmers; and
b. Calculation of PCI score for the problem of lack of good quality inputs-
PCI score of focal farmers = (33×3) + (6×2) + (5×1) + (6×0) = 116
PCI score of proximal farmers = (65×3) + (18×2) + (7×1) + (10×0) = 238
PCI score of control farmers = (96×3) + (71×2) + (14×1) + (9×0) = 364
PCI scores for rest of the problems were computed accordingly.

Majority of the farmers opined that the price of the production inputs were very much higher for them to meet the expenses. The PCI score of this problem was 136, 257 and 386 ranking by 1st, 2nd and 3rd in terms of focal, proximal and control farmers, respectively. Inadequate credit facility was another major problem faced by the farmers in the study areas. The credit lending process of different formal credit lending institutions was not transparent to them and as a result, they had to depend on different informal sources of credit like money lenders, relatives, friends, etc. The PCI score of this problem was calculated at 135, 258 and 387; which was ranked as 2nd problem along with the statements of all the three categories of farmers (focal, proximal and control farmers). Most of the farmers stated the selection of an appropriate crop rotation as a boring practice. With the statements of focal, proximal and control farmers, the PCI score of this problem was marked as 134, 261 and 388 which was ranked as 3rd, 1st and 1st, respectively. Tillage requirement for crop farming in Bangladesh does not permit minimum tillage in case of most of the crops which forestalls maximum crop production. The farmers of the study areas stated this as one of the major problems. The problem was ranked as 4th, 5th and 4th in accordance with the PCI score of 133, 246 and 373 with the opinion of focal, proximal and control farmers, respectively. Being a new dimension of crop farming, the practice of conservation agriculture was innovative to the farmers. The knowledge of the farmers on this aspect was not immensely transparent. Lack of appropriate knowledge on this farming practice was a great knotty issue for the farmers. As stated by focal, proximal and control farmers, this problem was ranked as 5th, 6th and 9th by means of PCI score of 132, 245 and 346, respectively.

Other problems like lack of good quality inputs, lack of transportation and storage facilities, weed infestation due to minimum tillage, outbreak of diseases, crop residues cannot be used as fuel, crop residues cannot be used as animal feed, lack of extension service and maintenance is difficult were ranked as 12th (with PCI score 116), 8th (with PCI score 128), 9th (with PCI score 127), 6th (with PCI score 130), 10th (with PCI score 121), 7th (with PCI score 129), 13th (with PCI score 113) and 11th (with PCI score 117), respectively in case of focal farmers; 10th (with PCI score 238), 11th (with PCI score 231), 7th (with PCI score 242), 12th (with PCI score 207), 8th (with PCI score 240), 4th (with PCI score 248), 13th (with PCI score 204) and 9th (with PCI score 239), respectively in terms of proximal farmers; and 5th (with PCI score 364), 13th (with PCI score 314), 12th (with PCI score 326), 11th (with PCI score 331), 10th (with PCI score 335), 6th (with PCI score 361), 7th (with PCI score 357) and 8th (with PCI score 356), respectively in stare of control farmers.

Conclusion

The study comes to an end with a conclusion that as a new resource saving farming practice, conservation agriculture was cherished highly and adopted successfully by the farmers. The study exposed that production cost of different crops was comparatively lower and return from production was moderately higher in this practice than traditional one which contributed to a noticeable increase in farmers' income. It is also revealed that majority of both focal and proximal farmers avowed about enhanced soil environmental circumstance after adopting conservation agriculture than before, while majority of control farmers stated about constant soil environmental condition. It is found from the estimates of probit model that three (minimum tillage operation, permanent organic soil cover and application of compost and vermicompost) out of six explanatory variables had significant influence on improving soil environmental quality due to conservation agriculture practice. High price of inputs, lack of institutional credit, lack of knowledge about conservation agriculture, boring practice of crop rotation, etc. were frequently faced by the farmers as problems in the study areas. Considering the findings of the study, it can be concluded that practicing conservation agriculture not only contributed to increase in farmers' income, but also protected the soil environment from effluence and damage. In real life, it can make superior use of available agricultural resources through combining limited external inputs with integrated management of soil, water and biological resources; and offer an opportunity for striking and reversing downhill resource degradation spiral, decreasing production costs and ensuring more resource-use-efficient, viable and sustainable agriculture by retaining a permanent or semi-permanent organic soil cover, crop rotation and minimum soil disturbance. Some indispensable policy guidelines have been arisen in this regard which are: Input and price intervention, scientific and technical training programmes and extension services by different government and non-government organizations should be properly implemented to elevate the consciousness about the importance of conservation agriculture practice on crop production among the farmers.

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Authors' Contributions

Md. Taj Uddin: Designed, collected and checked the analyzed data; supervised the draft manuscript and approved the final manuscript.

Aurup Ratan Dhar: Coordinated the study, collected and analyzed the data and prepared the draft manuscript.

Md. Hammadur Rahman: Supervised the work, reviewed the manuscript and contributed in data interpretation.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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