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Research Note

ECONOMICS OF CONSERVATION AGRICULTURE PRACTICES IMPOSED IN WHEAT-MAIZE-RICE CROPPING SYSTEM IN BANGLADESH

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ABSTRACT

Conservation agriculture (CA) is considered as a suitable crop management technique to offer higher crop productivity and economic benefits to farmers while safeguarding environment. To investigate these issues, an experiment was conducted under irrigated conditions using four treatments such as conventional agriculture (T₁), conservation agriculture (CA) (T₂), bed planting (T₃) and CA plus bed planting (T₄), imposed on component crops within a wheat-maize-rice cropping system during November 2010 to December 2015 at BARI research station, Gazipur, Bangladesh. The CA practices were based on retaining rice and wheat straw of 25 cm height and reduced tillage of single pass of power tiller operated tiller (PTOS) (in case of T₂) and single pass of power tiller operated bed planter (in case of T₄). ANOVA for adjusted 4 years pooled mean revealed no significant treatment effects for yield and economic analysis parameters ($P \geq 0.05$) for rice except BCR ($P \geq 0.05$) but the effects were significant for wheat, maize and wheat-maize-rice system for all economic parameters. Wheat yield across tillage treatments over four years ranged from 3,870 kg/ha in conventional to 5,182 kg/ha in CA. But maize, rice and W-M-R system ranged, respectively, from 5,810 kg/ha under conventional, 4,568 kg/ha under Bed, and 14,906 kg/ha under conventional practice to 7,175 kg/ha under CA, 5,032 kg/ha and 16,354 kg/ha under bed planting plus CA. Compared to conventional tillage the average maize and system yield across three CA practices were greater by 16% and 11.7%, respectively. Maize production cost ranged from Tk. 47,966/ha with the bed planting plus CA to Tk. 69,816/ha for conventional practices. Net returns and BCR of maize, however, ranged from Tk. 50,668/ha and 1.34 under FP to Tk. 101,932/ha under CA and 1.73 under bed planting plus CA, respectively. Likewise, total cost of production across treatments and years in rice ranged from Tk. 48,800/ha in three CA practices to Tk. 62,900/ha in conventional tillage while net return ranged from Tk. 18571/ha

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under FP to Tk. 35,550/ha in bed planting plus CA. It is concluded that while CA based tillage options may not have significant yield advantage over conventional tillage in maize and rice, they have significant advantages in terms of reduced production cost and labour use, and increased net returns. Considering the present climate change scenario and labour shortage during peak cropping season, policy should be focused on popularizing conservation practices as these improve grain productivity and save cost which yielded higher BCR thus farmers can get higher income by shifting their land from conventional agriculture to conservation practices.

Key words: Conservation agriculture, Wheat-maize-rice system, tillage, economic analysis.

I. INTRODUCTION

In Bangladesh typically cropping systems include *aman* rice (monsoon) followed by a second *boro* rice (R-R system) where water is abundant for cultivation. Where water is scarce for agricultural purpose wheat, potato, maize, vegetables and other crops are grown instead of *boro* for higher net return because cultivation of *boro* rice requires more water compared with other crops. R-R and rice wheat (R-W) system are well adopted by the farmers due to increase demand for food. A new system (Wheat-Maize-Rice) (W-M-R) experimented by the BARI shows high potentiality due to yield and income gains, a result of expanding feed demand for fish and poultry and conserving agriculture for long term sustainability. The main challenges of non-sustainability of agricultural systems in Bangladesh includes: soil erosion, soil organic matter decline, salinization, ground water depletion. These are caused mainly by intensive tillage, removal of entire crops including residues, inappropriate soil and water management and conventional mono-cropping. Therefore, a shift in farming from conventional to conservation agriculture is crucial for future productivity gains while sustaining the natural resources.

It has been evidenced that conservation agriculture aims at achieving sustainable and profitable agriculture thereby improving food security and livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, soil cover through appropriate residue management and profitable crop rotations. In South Asia, CA technologies have been developed, adapted and promoted since past several years with tremendous expansion potential to increase productivity and profitability sustainably. It has been evidenced that it increases input use efficiency, improve soil health, increase adaptive capacity of production systems to climate risks, reduce emissions and enhance soil carbon sequestration (Abrol and Sangar, 2006; FAO, 2010). CA has positive effect on soil and water conservation, environmental health and economic viability, and it has been regarded as an environmental friendly technology (Gupta et al., 2007; Thomas et al., 2007 and Lahmar, 2010). However, the serious situation of food security possess question about the impacts of CA practices on crop productivity and yield, especially in the developing countries like Bangladesh. Growing demand for food and feed resulted in expansion of rice-maize and or rice-wheat cropping system in Bangladesh. The replacement of aforementioned two cropping system with wheat-maize-rice cropping system will facilitate further intensification and the

intervention of CA could increase farmers income through improving productivity and profitability of not only for component crops but also for system as a result of higher production in some cases and reduced production costs. The system also has practical significance in increasing the area and production of both wheat and maize without losing rice productivity.

The effects of CA on crop yield can be variable (Farooq *et al.* 2011). For instance, CA may increase crop productivity and yield through improving soil fertility by conserving soil and water and sequestering organic carbon in farmland soils (Holland, 2004; Govaerts *et al.*, 2007 and Liu, 2010). On the other hand, CA may also have detrimental impacts on crop productivity and yield by altering soil physiochemical and biological conditions, such as decreasing soil temperatures in areas of high latitude and seasons with low temperature and aggravating weed and disease incidence (Boomsma *et al.* 2010; Kaschuk *et al.* 2010; and Deubel *et al.* 2011). However, the effects of CA on crop productivity depend on specific CA practices, soil type, cropping systems and management factors. One of the components of CA is crop residue management that contributes to increase crop productivity by conserving residual moisture (Sharma and Acharya 2000; Rahman *et al.* 2013), suppressing weeds and improving soil organic matter content (OM) and N use efficiency (Rahman *et al.* 2005).

CA based crop management technologies were introduced in Bangladesh by CIMMYT since 2002, and the progress has been tremendous both in demonstration and research plots. The total crop land area under CA in Bangladesh was 27.8 thousand ha in 2012 (Hossain *et al.* 2015), but the ratio of crop land under CA to total crop land area in Bangladesh is still lower than those in India and even Nepal (Hossain *et al.* 2015). The key factor limiting the application of CA in Bangladesh is the persistent uncertainty about the actual impacts of CA on crop productivity and yield as the country is now reach near to self sufficiency of cereal production. CA practices have been reported as effective in saving crop production cost and increasing crop yield (Hossain *et al.* 2015). Akter and Gathala (2014) also found that farmers in Bangladesh adopt CA technique rapidly due to increase crop yield and save cost. Uddin and Dhar (2016) studied CA practice and its impact on farmer's livelihood status and reported that CA could contribute the status of the farmers in terms of income. None of the above studies touch the yield and income gain by using CA techniques in intensive triple cereal cropping system. With this backdrop, the present study is confined the economic benefits of CA technique imposed in wheat-maize-rice cropping system comparing with conventional agriculture.

II. MATERIALS AND METHODS

Soil and Climate

A fixed plot field study was conducted for five consecutive years from November 2010 to December 2015 at the Research Farm of the Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh (24°36'91" N latitude, 88°66'17" E longitude). The research station belongs to AEZ 28 which is characterized by flood free highland with fine texture. The soil was deficient in organic matter, total N and most of the plant nutrients and the sub-surface

soil (15-30 cm) was more deficient in different nutrients as compare to surface soil (0-15cm). The initial soil pH of the experiment site was 6.5 at the surface and 6.7 at the sub-surface. The climate of the region is sub-tropical with mean annual rainfall (1960-2015) of 169.77 mm, 88% occurring during the rainy season (June-September). The wheat growing period (November to March) is fairly dry and the crop expose to higher temperature at reproductive to grain filling stages. The mean rainfall, minimum and maximum temperature of the experimental site is presented in Figure 1.

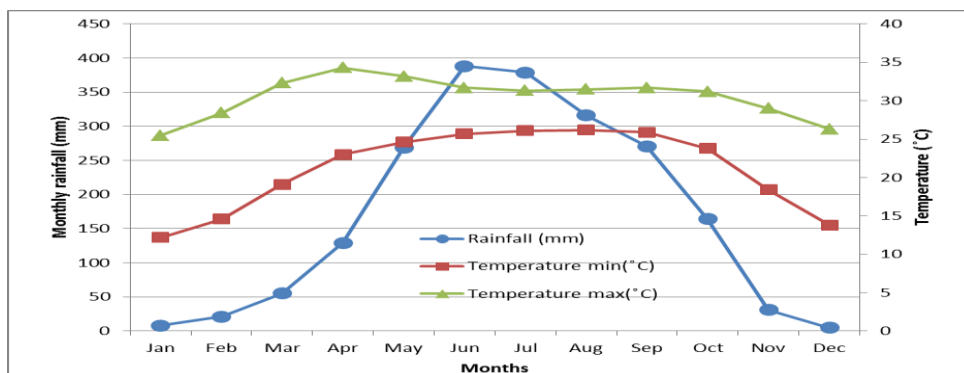


Figure 1: Mean (1960-2015) rainfall, maximum and minimum temperatures of the BARI research station Gazipur.

Experimental design and treatments

The experiment was laid out in a randomized block design with three replications of four treatments imposed in plots measuring 10m × 6m in size. The treatments were:

- T_1 : *Conventional practice/farmer's practice (FP)*
 Conventional practice including broadcasting wheat seeds on well tilled soil followed by line sown maize then puddle transplanted (PTP) aman rice, all with full tillage and without any crop residue retention.
- T_2 : *Conservation agricultural practice (CA)*
 The CA consist of wheat sown by single pass of Power tiller operated seeder (PTOS) with anchored/standing rice straw (25 cm in height) followed by no-till maize in plot with anchored/standing wheat straw of about 25 cm height and then PTP aman rice.
- T_3 : *Bed Planting (Bed)*
 The treatment comprise of wheat sowing by power tiller operated bed planter (PTOBP) followed by no till maize then PTP aman rice without any crop residue retention.
- T_4 : *Bed + CA*
 The treatment is similar to T_3 , but included rice and wheat straw/residue retention as in T_2 .

Crop variety and intercultural operations

Three crops varieties such as BARI Gom-26, BARI Hybrid Maize 7 and BINA Dhan 7 were introduced as the first, second and third crop respectively, in the system. The recommended rates of fertilizers for wheat ($N_{120}P_{30}K_{50} S_{20}B_1$), maize ($N_{200}P_{50}K_{80} S_{40}Zn_5B_2$) and rice ($N_{80}P_{30}K_{50}S_{20}$) were applied manually for all the crops. Seeds of wheat and maize and seedlings of rice were used as planting materials. Wheat seeds were broadcasted at the rate of 140 kg/ha in case of FP (T_1) whereas wheat seeds were sown using PTOS and Bed planter in case of T_2 , T_3 and T_4 and the seed rates were 120, 100 and 100 kg/ha, respectively. Maize seed rate was 30 kg/ha for all the treatments and rice seedlings were transplanted maintaining row to row spacing of 20 cm and plant to plant spacing of 15 cm. The wheat crop was irrigated uniformly to bring the soil moisture near to field capacity (29% by weight) during CRI, booting and grain filling stages. To ensure germination and stand establishment two to three time irrigations were applied at the early growth stages of maize and no irrigations were required after the onset of monsoonal precipitation. The rice crop was rain-fed for all the years. Wheat was sown between 20 and 25th November for all the years. After wheat harvest maize seeds were sown within 10-15th March (Kharif-1 season), which matured within 110-115 days in mid-July. Then rice was transplanted at the end of July as the 3rd component crop in the system. Upon maturity, wheat and rice were harvested about 25 cm above the ground as per prescribed treatments in cases of T_2 and T_4 to ensure the retention of residue about 30% wheat and rice in the plots. Similarly, the maize crop was cut above the ground and allowing the base and its root system to retain in the soil. Thinning and all other intercultural operations of maize were done duly following the recommended practice with the exception of earthen-up. Weeding and all intercultural operations were done duly those were same for all plots.

Crop harvest and yield estimation

At maturity samples were harvested from the central area of 6m x 4m in each plot then the samples were threshed, grains were sun dried and then moisture content of grain samples were measured to converted grain yields (kg/ ha) at 12% moisture content for wheat and 14% for maize and rice. Total biomass (grain + straw) was weighed with a spring balance. Straw yields were reported on air dry weight basis. Harvest Index (HI) was calculated as grain yield divided by total biomass yield on a per hectare basis.

Cost and Return

Partial economic analysis for various alternative tillage treatments was conducted by using the variable costs and return from sale of wheat, rice and maize grain, and wheat straw, maize stover and rice straw. The variable costs included various input costs, machinery costs and labour use for different treatments. Input costs included costs for seed, fertilizers, manure, irrigation, while machinery costs included costs for hiring machinery for tillage. Labour uses included the use for operations such as tillage, transplanting/sowing, irrigation, application of fertilizers, weeding, harvesting and threshing. The unit of human labour was based on labour days/ha and was calculated by recording the time required for each agricultural activity and

converting them to labour days (8 hours being equivalent to 1 labour day). The cost of labour was calculated using the average wage rate for the study years.

Gross return was calculated by multiplying the total volume of production by the average prices (the average of the farm gate price) of that product in the harvesting period. The net return for a particular treatment was calculated based on grain and straw production under the treatment and their market value in the particular production year. Net income for all treatments was calculated by subtracting expenses for all variable inputs from the calculated gross return. The benefit cost ratio (BCR) was computed as the ratio of gross return and cost of production.

Data Analysis

After ensuring normality and homogeneity of variance of the data they were subjected to repeated measures multivariate analysis of variance (MANOVA) and analysed for significance using appropriate F-test by using SPSS 20, separately for wheat, maize, rice and the W-M-R system considering year and treatment and their interactions as factors. Pooled treatment adjusted means were compared by Turkey's honest significant difference (HSD) at $\alpha = 0.05$. Adjusted means are statistical averages that have been adjusted or corrected by the model for the imbalances or outliers present in the data sets which otherwise would have an impact on the calculated means. Due to non-significant effect of year, pooled data over the four cropping seasons were taken into consideration for analysis of crop yield and system productivity.

III. RESULTS AND DISCUSSION

Effect of Conservation Agriculture on Crop yield, yield variability and system productivity

Wheat yields in all treatments and years averaged 4587 kg/ha. This is considerably greater than the national average of 3031 kg/ha (BBS, 2015). This might be attributed to favourable rainfall distribution pattern and soil fertility of the site coupled with the use of an improved wheat variety and application of recommended agronomic practices including CA. In most cases, results from long term conservation agriculture studies have shown that wheat yields in the initial years are not significantly different from conventional practices (Thierfelder et al., 2012), but profitability is high because of reduction in production costs. Immediate yield benefits of CA were observed only in some field studies such as in Ngwira et al. (2012) where benefits of CA on wheat yields were realized in the very first year itself in one of the study sites. Use of a seeder or bed planter ensures seed placement at desired soil depth (3-5cm), which appears to result in better germination there by plant establishment. Furthermore the retention of straw in the soil is likely to have influenced the hydraulic properties of the soil, resulting in an improved crop stand and more spikes/m² in wheat and cobs/m² in maize. Conservation practice can reduce evaporation from the soil (Sharma and Acharya 2000), and helps to mediate soil temperatures and thus ensured germination and stand establishment (Erenstien, 2002). CA practices contributed to the yield of upland wheat and maize crop by conserving soil moisture and indirectly by influencing crop growth factors and contributing

soil nutrient contents. There are also other numerous studies regarding the variability of short term yield response (positive, neutral, or negative yield responses) to conservation agriculture practices (Lal, 1986; Gill and Aulakh, 1990, Mbagwu, 1990; Mupangwa et al., 2012). In general, CA yield benefits took longer to establish a clear upward trend. The reason is generally attributed to the time necessary to build soil fertility and to adapt to the new conservation agriculture system, a phenomenon called ‘age hardening’ for soil transitioning. In this study the yield benefit of CA was found from the initial year that was due to the direct effect of CA in conserving soil moisture during the drier period in entire wheat growing season and early growth period in maize.

The ANOVA for the adjusted 4-year pooled mean revealed significant treatment ($P \geq 0.05$) effects for grain and HI of wheat and for biomass and HI of maize (Table 1). Year effects were significant ($P \geq 0.05$) for rice of grain, W-M-R system of grain, rice of biomass, system of biomass, and maize HI. The year effect of rice indicates that in the initial stage of experiment the yield is comparatively lower than the later stage which further indicates that the system brings productivity grain.

Wheat

Grain yield of wheat four years across the tillage treatments ranged from 3870 kg/ha conventional/farmer practice to 5182 kg/ha to Bed plus CA. Biomass yield ranged from 9,593 kg/ha under FP to 11,965 kg/ha on Bed plus CA, with significant differences observed for grain and no significant effect differences observed for biomass production. Generally biomass production is closely related to yield and the treatment that results higher yield also resulted in high biomass production. In present experiment, wheat and rice crop were harvested from 25 cm above the ground in case of treatment CA and Bed plus CA whereas crops were cut from the soil surface in case of FP and Bed. Therefore the biomass of later couple of treatment was greater than former couple of treatment. HI of wheat was similar (0.40-0.43) across all treatments (Table 1). Box plots showed highest mean and median yield of wheat on Bed planting plus CA with the lowest under FP (Figure 1). The inter-quartile range (IQR-a measure of variability, based on dividing a data set into quartiles) was highest for CA (1169 kg/ha) and lowest for FP (547 kg/ha), indicating higher variability for the former than the later.

Table 1: Effect of CA on the yield performance of wheat, maize, rice and system (4yr adjusted pooled mean) during 2011-15

Tillage options	Grain yield (kg/ha)			System	Biomass (kg/ha)			System	HI		
	Wheat	Maize	Rice		Wheat	Maize	Rice		Wheat	Maize	Rice
FP	3870 _a	5810 _a	4745 _b	14906 _b	9593 _a	16389 _a	10284 _b	39690 _b	0.40 _a	0.36 _b	0.46 _c
CA	5074 _a	7175 _a	4982 _b	16163 _b	11729 _a	22073 _a	9843 _b	40500 _b	0.43 _a	0.33 _b	0.50 _c
Bed	4222 _a	5975 _a	4568 _b	16262 _b	10760 _a	18141 _a	9833 _b	40770 _b	0.40 _a	0.33 _b	0.46 _c
Bed+CA	5182 _a	6929 _a	5032 _b	16354 _b	11965 _a	21279 _a	9836 _b	40764 _b	0.43 _a	0.33 _b	0.51 _c

Within a column, means followed by the same letter are not significantly different at 0.05 level of probability by Tukey's HST test.

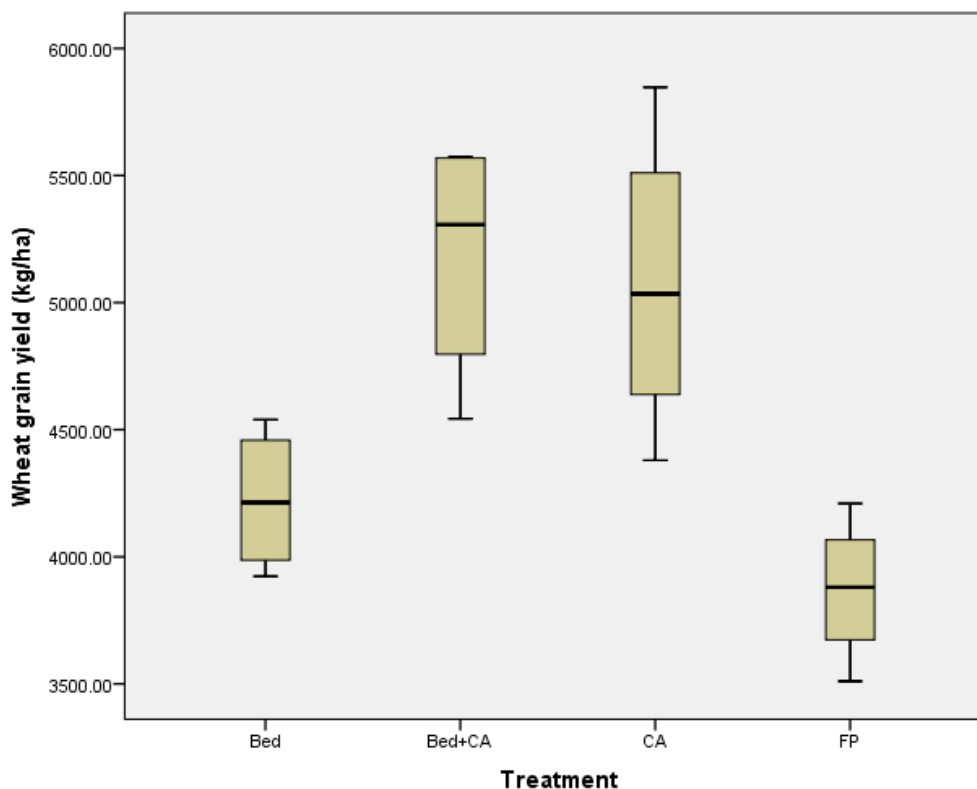


Figure1. Box plots showing variability of wheat grain yields under different tillage options across 4 years of experimentation

Maize

The year averaged maize yield in all treatments about 6693 kg/ha which is considerable greater than the national average of 2846 kg/ha (BBS, 2015). Maize grain yields over four years ranged from 5810 kg/ha with FP to 7175 kg/ha on CA, while biomass yield ranged from 16389 kg/ha under former to 22073 kg/ha with the latter (Table 1). For grain yield, all three CA based tillage and crop establishment options, were not significant different from each other, although maize sown on CA performed significantly better than under conventional tillage. But the biomass yield shown significant difference all the three CA based tillage options. Compared to conventional tillage the average grain yield of maize and system across three CA practice was 15 and 9.08% greater. The HI of maize was not significantly different across the tillage methods, and averaged 0.34. Box plot of grain yield of maize under the different treatment options showed highest mean and median yield on the CA (Figure 2). The IQR was highest with FP (1597 kg/ha) and lowest for the Bed (905 kg/ha), indicating higher variability in maize yield under FP.

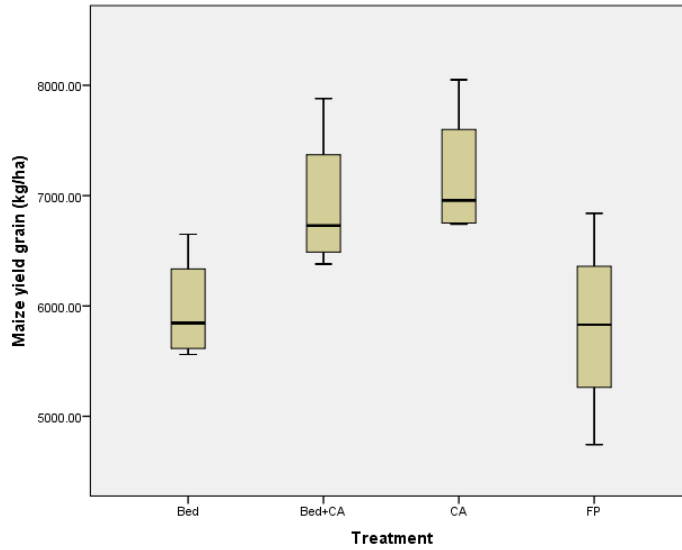


Figure 2. Box plots showing variability of maize grain yields under different tillage options across 4 years of experimentation

Rice

Grain yield of rice across the treatments ranged from 4568 kg/ha under Bed to 5032 kg/ha under Bed plus CA. Biomass yield ranged from 9833 kg/ha under Bed to 10284 kg/ha on FP, with no significant differences observed for biomass production but significant difference observed for grain yield of rice. HI of rice was similar (0.46-0.51) across all treatments (Table 1) and significant differences observed across treatments. Box plots showed highest mean and median yield of rice on Bed planting plus CA with the lowest under FP (Figure 3). The IQR was highest for Bed plus CA (1323 kg/ha) and lowest for FP (932 kg/ha), indicating higher variability for the former than the latter.

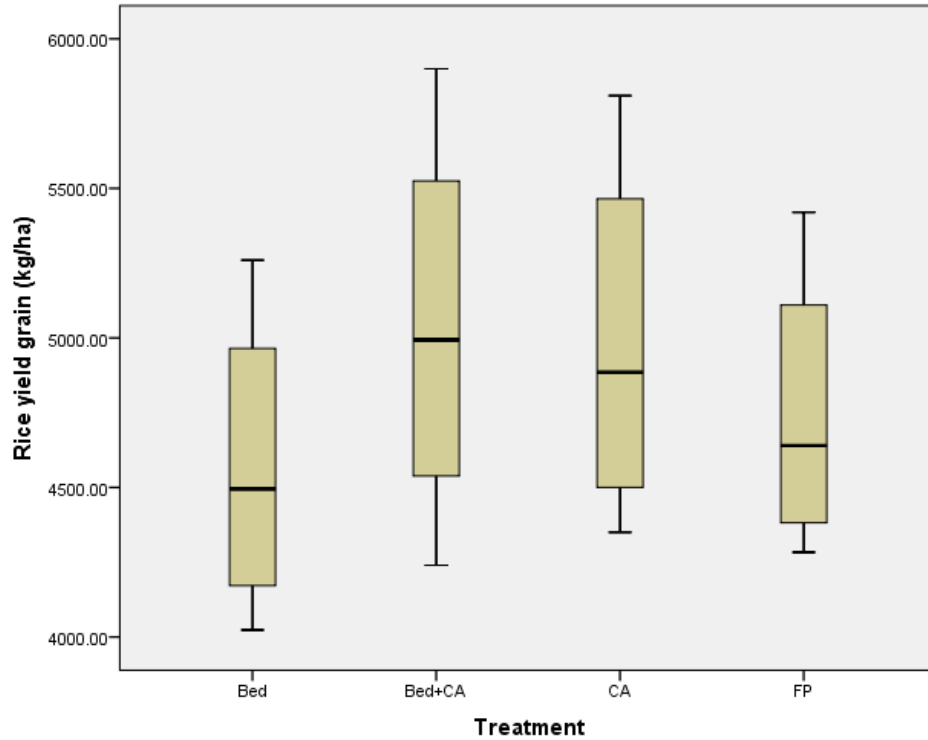


Figure 3. Box plots showing variability of rice grain yield under different tillage options across 4 years of experimentation

Wheat-maize-rice system

Because of the lack of significant differences on the maize and rice, W-M-R system productivity followed a similar response to wheat. Total system level grain productivity ranged from 14906 kg/ha with conventional tillage to 16354 kg/ha on Bed plus CA. System level biomass productivity ranged from 9833 kg/ha in the Bed to 10284 kg/ha with the FP (Table 1). Compared to conventional tillage, average system level biomass and grain yield across CA, Bed and Bed plus CA decreased by 0.55% and increased by 9.08%, respectively. Box plot showed highest mean and median system productivity for the Bed plus CA with the lowest under conventional tillage (Figure 2). IQR was the highest for CA (3534 kg/ha) and the lowest for conventional tillage (2074 kg/ha). Other tillage options exhibited intermediate variability.

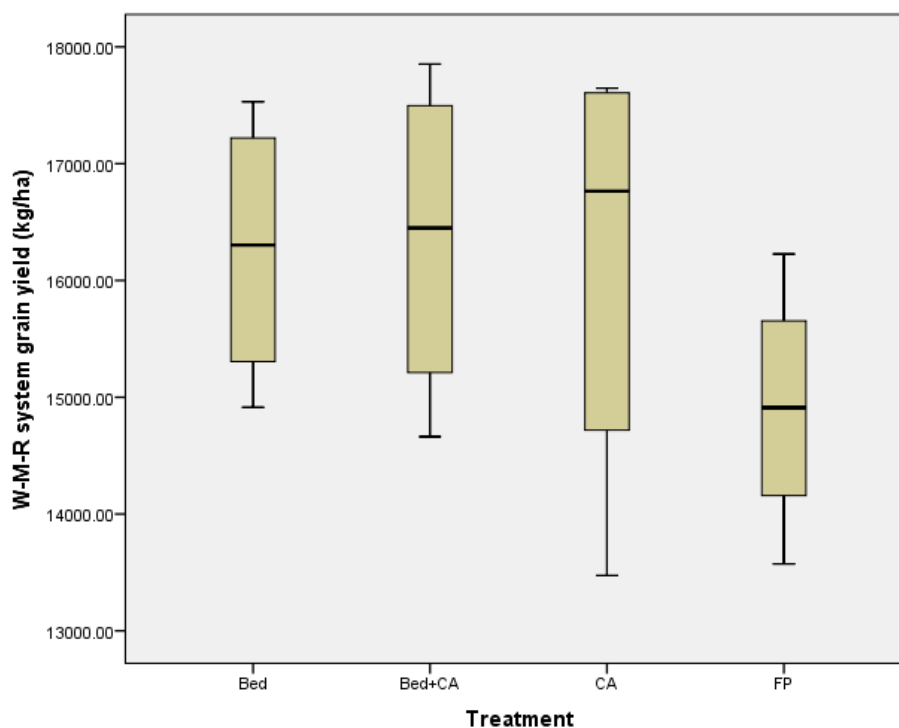


Figure 4. Box plots showing variability of W-M-R system grain yield under different tillage options across 4 years of experimentation

Effects of conservation agriculture on partial economics

There was no significant year and year \times treatment effects for gross return or net income from wheat, maize, rice or the total W-M-R system. The treatment effect was, however, significant for the production cost and BCR at the system level (Table 2). Year effects were also not significant for production cost, gross return and net return of wheat. The treatment, year and year \times treatment effect on BCR is significant for all cases. The treatment effects were not significant ($P \geq 0.05$) for production cost, gross return and net return in wheat, they were significant ($P \geq 0.05$) in maize and rice for production cost.

Wheat

There were no significant treatment differences for any of the economic parameters in wheat except BCR (Table 2). Total cost of production across treatments and years in wheat ranged from Tk. 60650/ha in Bed plus CA to Tk. 71586/ha in conventional tillage while gross returns ranged from Tk. 97046/ha in conventional tillage to Tk. 124005/ha in CA (Table 2 and Figure 3). Likewise, net income ranged from Tk. 25459/ha in conventional practice to Tk. 63657/ha in Bed plus CA and the BCR from 1.34 in conventional tillage to 1.90 in CA (Table 2).

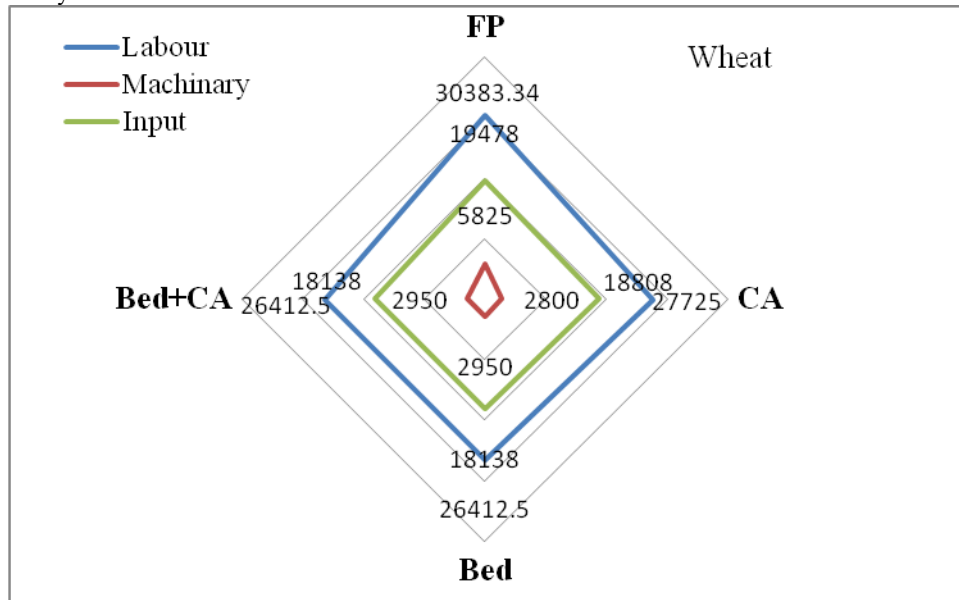
Maize

In contrast to wheat, the results of the cost and return showed large differences in maize. Maize production cost ranged from Tk. 47966/ha with the Bed planting and CA to Tk. 69816/ha for conventional practices (Table 2 and Figure 3). Gross returns from maize ranged from Tk. 120485/ha in conventional tillage to Tk. 150398/ha in CA, while net return ranged from Tk. 50668/ha in the former to Tk. 101932/ha with the later.

Table 2. Effect of conservation agriculture options on partial economies of wheat, maize, rice and system (4 yr adjusted pooled mean) during 2011-2015

Tillage operations	Production cost (Tk/ha)				Gross return (Tk/ha)				Net return (Tk/ha)				BCR			
	Wheat	Maize	Rice	System	Wheat	Maize	Rice	System	Wheat	Maize	Rice	System	Wheat	Maize	Rice	System
FP	71586	69816a	62900a	204302a	97046	120485	81477	29900	25459	50668a	18571	94700a	1.34a	1.34b	1.3a	1.46a
CA	65133	4846ab	48800a	162399a	124005	150398	83608	358012	58872	101932a	34808	195613a	1.90a	1.90ab	1.71	2.2ab
Bed	63225	47966a	48800a	159991a	108452	124805	78358	311616	60387	76839	29558	166784	1.71a	1.71ab	1.60	1.94a
Bed+CA	60650	47966a	48800a	157416a	108452	124805	84350	356395	63657	97194a	35550	196403a	1.00a	2.002a	1.73	2.25a

Within a column, means followed by the same letter are not different at the 0.05 level of probability by Tukey's HST test.



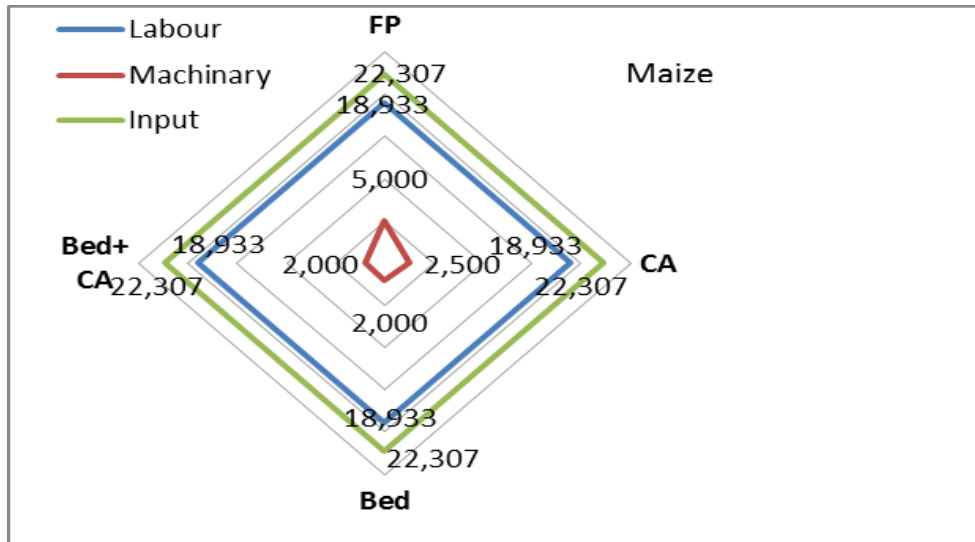
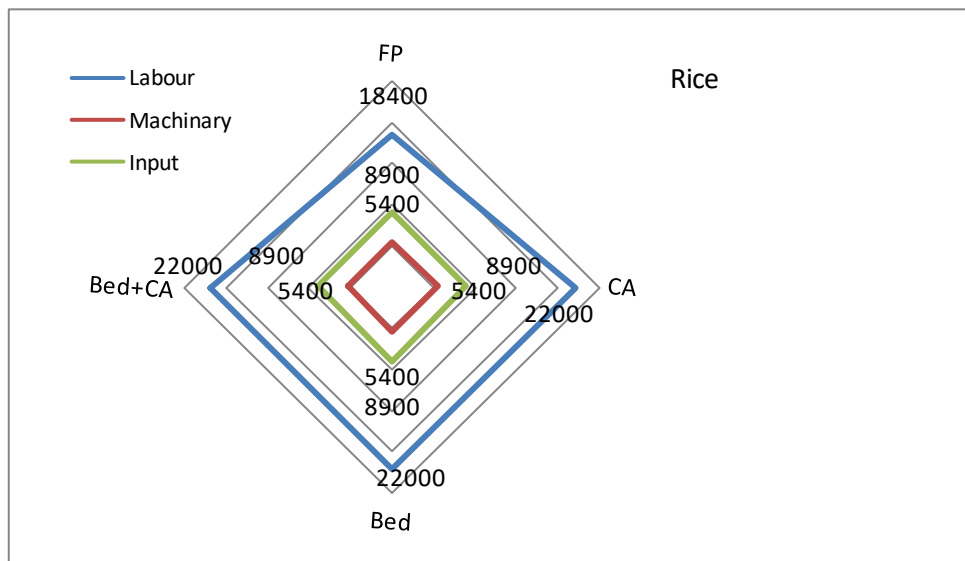


Figure 3. Cost of production (4 yrs mean) under different tillage options for wheat and maize. Numbers in each spider diagram indicate amount in Tk.



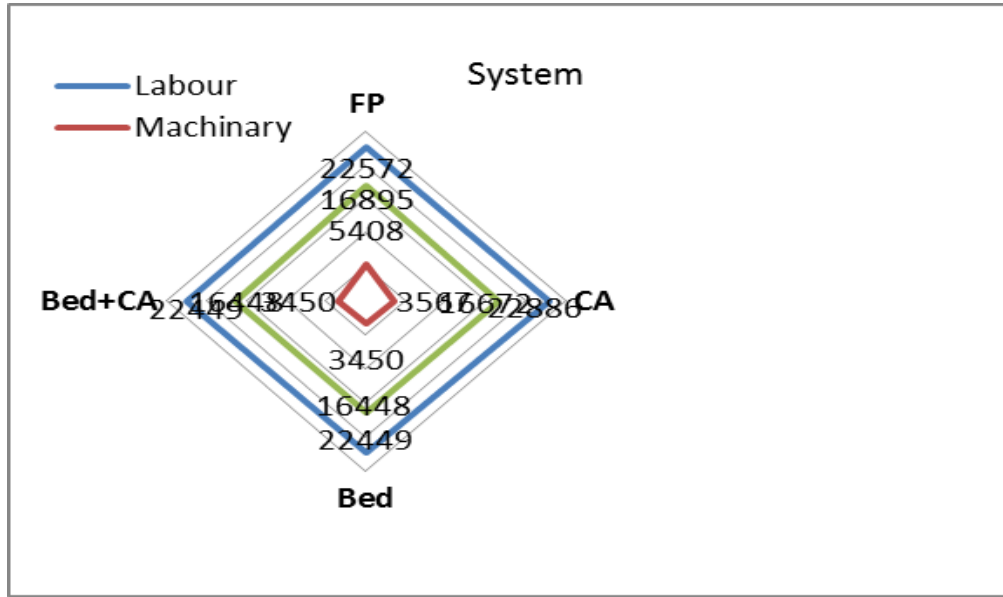


Figure 4. Cost of production (4 yrs mean) under different tillage options for rice and system. Numbers in each spider diagram indicate amount in Tk.

BCR ranged from 1.34 with conventional tillage to 2.0 in Bed planting plus CA. All the economic parameters were significantly different, except the gross returns. However, there were no significant differences among the three CA based tillage options for net return and BCR. BCRs of all the tillage options were similar but were significantly higher than that of the conventional tillage. Compared to conventional tillage, gross returns from the CA and average gross returns across the CA, Bed planting and Bed planting plus CA, increased by 24.8 and 10.7%, respectively. Likewise, compared to the conventional tillage, average net income across the CA, Bed planting and Bed planting plus CA increased by 81.6%. Compared to conventional tillage, average system-level BCR across all other CA tillage options also increased by 45.8%.

Rice

There were no significant treatment differences for any of the economic parameters in rice except production cost (Table 2 and Figure 6). Total cost of production across treatments and years in rice ranged from Tk. 48800/ha in three CA practices to Tk. 62900/ha in conventional tillage while gross returns ranged from Tk. 78358/ha in Bed planting to Tk. 84350/ha in Bed planting plus CA (Table 2 and Figure 4). Likewise, net return ranged from Tk. 18571/ha in conventional practice to Tk. 35550/ha in Bed plus CA and the BCR from 1.3 in conventional tillage to 1.73 in Bed planting plus CA (Table 2).

System

The cost of production for the W-M-R system across four years was the highest in conventional tillage (Tk. 204302/ha) and the lowest for the Bed planting plus CA (Tk. 157416/ha). All other economic parameters (gross return, net return, BCR) for W-M-R system were not significantly different for different tillage treatments but were significantly lower for conventional tillage (Table 2). Gross returns across four years for the conventional tillage was lowest (Tk. 299003/ha) and highest in the CA (Tk. 358012/ha). Net returns was also significantly lower for conventional tillage (Tk. 94700/ha) than rest of the tillage options (Tk. 166784-Tk.196403/ha), as was BCR for the conventional tillage (1.46) compared to the other treatments (1.94-2.25). Compared to conventional tillage, average system level gross returns across three CA based practices was 14.3% greater.

IV. CONCLUSION AND POLICY RECOMMENDATIONS

The agriculture in Bangladesh primarily focuses on finding a sustainably suitable agricultural technology that meets the demands of smallholder farmers while maintaining or improving soil fertility. Though there is no universal strategy to end challenges to food security in the country but it was evident from the study that combining and simultaneously applying low input conservation agriculture practices coupled with residue retention helps in optimizing resource use efficiency, reduce production cost and increase in net return and thus BCR. Higher yield, total return and net return and thus BCRs of the component crops within an intensive wheat-maize-rice cropping system was found under the conservation agricultural practices. Results from experiments demonstrate that conservation agriculture along with bed planter and crops residual retention enhances productivity of component crops in wheat-maize-rice system. The results demonstrate the potential of conservation agriculture system for increasing grain yield and reduce cost of production. That said conservation agriculture is recommended for reducing cost of production and increase the profit which will in turn reduce the pressure of survival of farming communities.

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