Project

Report On

"Improvement of cereal-based cropping systems following the principles of conservation agriculture under changing agricultural scenarios in Bangladesh"

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EDGE: BU-CSE Digital Skills Training

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1.Introduction

In South Asia, rice, wheat and maize are the major cereal crops grown often in rotation with non-cereal crops such as potato, mustard and legumes (Balasubramanian et al., 2012). Among them, rice and wheat provide the staple food for hundreds of millions of people. Maize is mainly a feed crop but it is also a food crop in many poverty-stricken areas, especially in the hilly areas. These crops greatly influence the livelihoods and health of the urban and rural poor in these regions. Cereal production needs to increase by about 2% per annum over the next four decades to ensure food security in South Asia (Ray et al., 2013). National mean yields of these cereals in South Asia are below global averages except for maize in Bangladesh, and large yield gaps of about 50% or more exist (Balasubramanian et al., 2012).

Bangladesh has increased rice production 1.8 times during the last 20 years with almost no increase in rice area (FAO, 2012). However, because of the continuous increase in population, rice demand is projected to be 56% higher in 2050 than in 2001 and demand for other dominant cereals such as maize and wheat is projected to be more than 10 times and twice, respectively, in 2050 (Mukherjee et al., 2011).

2.Materials and methods

2.1.Experimental site and seasons

The study was conducted at the experimental farm of the Bangladesh Agricultural Research Institute (BARI) in Gazipur, Bangladesh (23°59^{r}01^{rr} to 23°59^{r}02.2^{rr}N and 90°24^{r}08^{rr} to 90°24^{r}12.6^{rr}E). The experiment was established in 2009 as a production-scale trial with a long-term perspective of at least 10 years involving four rice-based cropping systems. The climate of Gazipur is hot subhumid with total annual (December–November) rainfall during the study period was 1309 mm in 2009–2010, 1829 mm in 2010–2011 and 1359 mm in 2011–2012.

The lowest mean monthly minimum and the highest mean monthly maximum temperatures during three years were as follows:2009–2010, 11.21 °C in January and 35.13 °C in April, respectively; 2010–2011, 10.31 °C in January and 33.10 °C in May, respectively; and 2011–2012, 12.96 °C in January and 34.31 °C in May (Fig. 1). Crop production was distributed across the three seasons common in the country: Rabi, also called Boro (November to March); pre- monsoon Kharif-1, also called Aus (April to June); and monsoon Kharif-2, also called Aman (July to October). The trial began in Boro 2009–2010.

Table-1 : Monthly Total rainfall and monthly average maximum and minimum temperatures during cropping years, 2009–2010

Name of Month	Cropping Year 2009-2010		
	Temperature		Rainfall
	Max	Min	
January	220	213	225
February	325	319	250
March	330	325	350
April	435	429	450
May	540	535	550
June	637	632	350
July	533	527	320
August	431	422	220
September	329	321	330
October	225	219	220
November	223	217	250
December	321	215	360

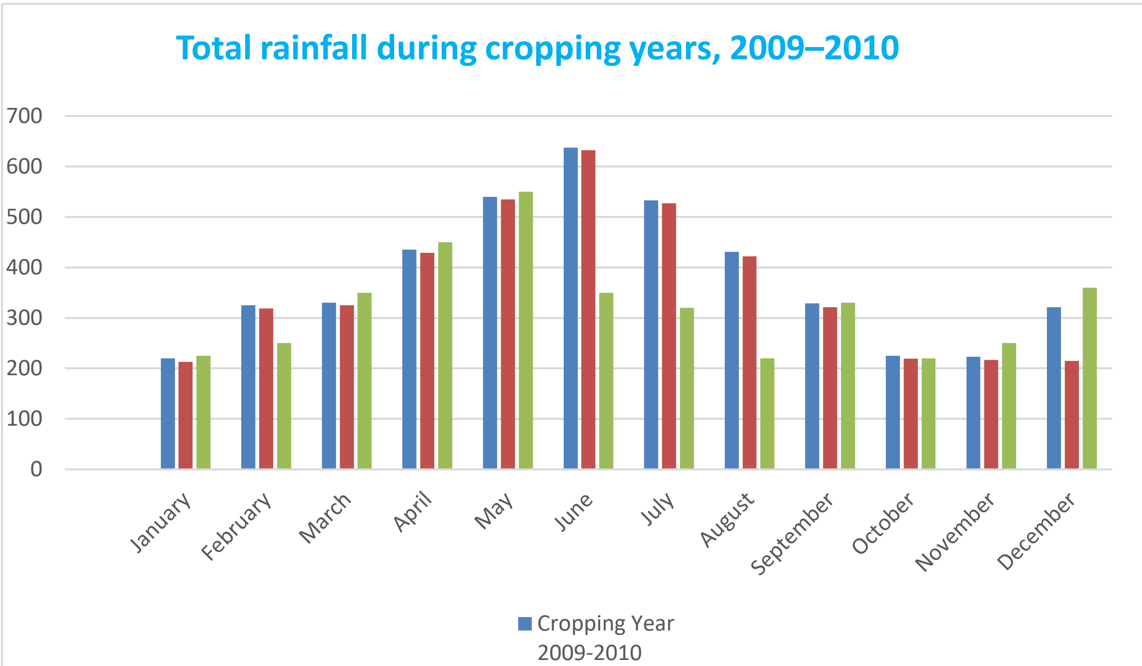


Fig. 1. Monthly Total rainfall and monthly average maximum and minimum

2.2.Experimental design and treatments

Four cropping system treatments referred to as scenarios (S) were designed based on different drivers of agricultural change. The scenarios varied from each other in tillage, crop establishment, residue management, crop rotation and other management practices. Treatments referred to as scenarios 1–4 (S1–S4) were assigned to individual plots and replicated thrice in a randomized complete block design. Scenario details involving crop management and various field activities are provided in respectively.

2.2.1.Scenario 1(business as usual Farmers' practice)

This scenario represents current farmers' practices of crop rotation, crop varieties and management (tillage and crop establishment, and residue), which were based on an on-farm survey conducted in 263 farmers' fields during 2006–2008 in the neighboring area.

Rice (Boro)–fallow (Aus)–rice (Aman) was the crop rotation because it is the predominant cropping pattern covering more than 80% of the cultivated area in the region. In both seasons (Boro and Aman), rice was grown by transplanting four to six seedlings per hill in puddled soil prepared by intensive wet tillage. Boro rice was irrigated but Aman rice was rainfed. Rice was harvested manually at or near ground level, leaving 5–10 cm standing biomass from the ground which was incorporated during land preparation of the next crop.

2.2.2.Scenario2 (best management practices with conventional tillage)

Scenario 2 was designed to increase productivity, input use efficiency and profitability of the rice (Boro)–fallow (Aus)–rice (Aman) crop rotation through the use of BMPs. Rice was manually trans- planted into puddled and leveled soils prepared by three to four passes of a power tiller followed by two passes of the power tiller with wooden plank for leveling. At harvest, 30 cm standing rice biomass was incorporated during land preparation of the next crop.

2.2.3.Scenario 3 (best management practices with reduced tillage)

Similar to S2, S3 had the objective of increasing productivity, input use efficiency and profitability of the rice (Boro)–fallow (Aus)–rice (Aman) crop rotation through the use of BMPs. In addition some components of CA were included to specifically address shortages of labor and water. Intensive wet tillage (puddling) was avoided by transplanting in non-puddled soil. At harvest, 30 cm standing biomass was left and incorporated during land preparation of the next crop. Boro rice was transplanted manually and Aman rice with a mechanical transplanter into reduced-till non- puddled soils. In Boro, soils prepared by one to two passes of a power tiller operated seeder (PTOS) in dry condition and prior to transplanting water applied. In Aman, soils prepared by two passes of a power tiller in wet condition.

2.2.4.Scenario 4 (crop diversification with best management practices and reduced to zero tillage)

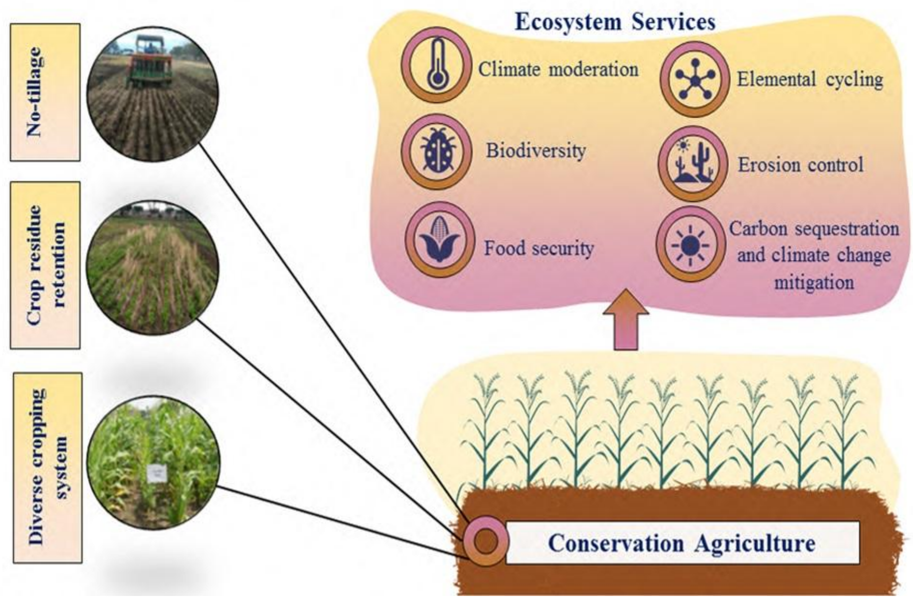
This scenario was designed for water- and labor-scarce environments to improve system productivity and profitability through diversified cereal-based cropping systems with BMPs and CA. In this scenario, the crop rotation was potato (Boro)-relay maize (or Mungbam) (Aus)-rice (Aman). In 2011, maize failed to grow because of untimely and excessive rainfall. In 2012, Mungbam instead of maize was grown after the harvest of potato. Rice was transplanted into reduced-till non-puddled soils prepared by one to two passes of a power tiller in wet condition. Transplanting was done manually in 2010 and 2011 and with a mechanical trans- planter in 2012. Potato was planted manually into soils prepared with reduced tillage (four to five passes of a power tiller followed by two passes of laddering) while maize and Mungbam were sown with zero tillage (ZT). At harvest, 30 cm standing rice biomass was left and incorporated during land preparation of the next crop and full residues of non-rice crops were retained on

2.3.Soil sampling and analysis

Before imposing the experimental treatments, baseline soil samples were collected from three locations in each of the four grids measuring 20.5 m × 17.5 m in each plot at 0–15-cm and 15–30-cm soil depths using an augur of 5-cm diameter. Each of the four corners of each plot had one grid. The depth-wise soil samples from each grid cell of a plot were composited, air-dried, ground to pass through a 2-mm sieve and stored in a plastic jar until analysis. The soil samples were analyzed for pH, electrical.

2.4.Data measurement and calculation

The human labor used in all operations and management practices, amounts of all inputs and outputs, electrical energy used for irrigation, input–output prices,



wage rate for labor and machinery rent were recorded for each plot.

2.4.1.Crop yield estimation

Grain and straw yields of rice, grain and stover yields of maize, tuber and shoot yields of potato and grain and shoot yields of mung- bean were determined by manually harvesting five areas (one from each of four grid cells and one from the middle of the plot) in each plot at physiological maturity. Each harvest area was 6 m^2 for rice and 12 m^2 for each of maize, potato and Mungbam. Grain yields of rice, maize and Mungbam were adjusted to 14%, 14% and 12% moisture content, respectively

The textural class was determined by the United States Department of Agriculture (USDA) system.

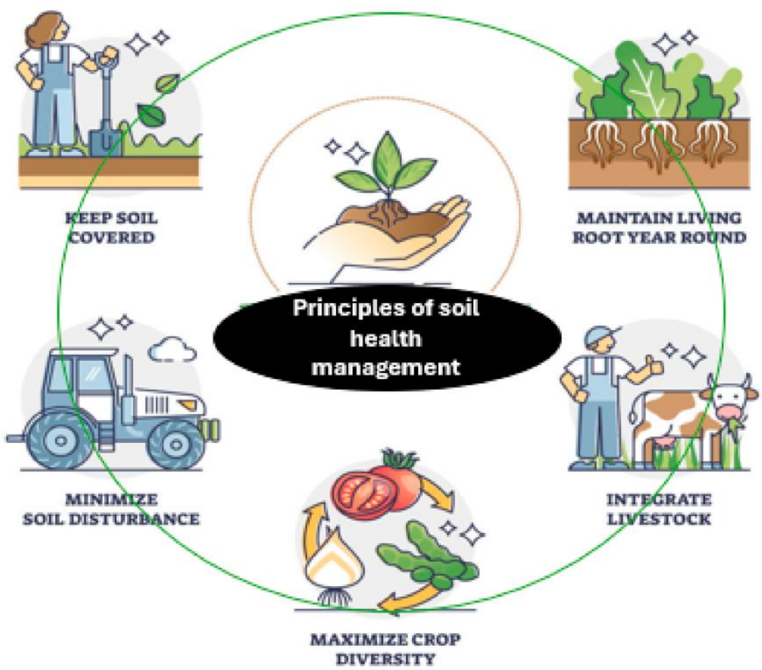
2.4.2.Water measurement and water productivity calculation

In the experimental area, all the plots were connected by a 5-cm polyvinyl chloride (PVC) pipeline installed on the bunds on one side of each plot with an outlet to the plot at the center for precise water application and measurement. The PVC pipeline was significant difference test at $P < 0.05$ level was used to test the differences between the scenario means. The scenario × year interaction effects were always significant for all parameters except GR, NR and BCR for both kno.

3.Results and discussion

3.1.Weather

Boro rice received insufficient rainfall and hence largely depended on irrigation, but with high solar radiation. During trans- planting to harvesting (late January to early May), Boro rice had 49–50 mm, 281–291 mm and 233–234 mm of rainfall in the first, second and third year, respectively (Table 6). In Boro, first year had lower rainfall but relatively higher solar radiation than sec- ond and third years. Maize (late January to late May) also received insufficient rainfall of



less than 300 mm in first and third years, and

slightly more than 500 mm in second year. In the second year, 40% of the total rainfall of 517 mm occurred at 80–85 days after planting of maize, resulting in waterlogging and crop failure.

During the Aman rice-growing period (mid-July to late November), total rain- fall was 788 mm, 1006 mm and 474–630 mm in the first, second and third year, respectively. In the third year, the total amount of rainfall varied among the scenarios (490 mm in S1, 599 mm in S2, 630 mm in S3 and 474 mm in S4) because of variable transplanting dates during 19 July to 1 August and shorter field duration by 35 days in S4 compared with S1–S3. Earlier transplanted rice having similar growth duration in S1–S3 received more rainfall. Although rice was transplanted earlier in S4, it received the lowest amount of rainfall because of early harvest of the shorter-duration variety. The transplanting dates were also variable during 21 to 29 July in the first year and 23 July to 6 August in the second year but this did not influence the total amount of rainfall because it was the same within these periods in both years. The rice variety used in S4 was 20 days early maturing in the first and second year, which also did not affect the total amount of rainfall. Despite high rainfall in the second year, irrigation was required at the booting/flowering stage because of unfavorable rainfall pattern (data not shown). Irrigation was also required in the third year at booting/flowering stage.

3.2.Crop and cropping system yield

3.2.1.Boro rice, rice equivalent yield of potato and Aman rice

Boro rice yields in S1–S3 and rice equivalent yield (REY) of potato in S4 ranged from 4.9 to 6.6 and 7.1 to 9.9 Mg ha^{-1}, respectively, across years. Boro rice yields in S2 and S3 were always similar but significantly higher than in S1 and lower than REY of potato in S4. Compared to S1 (farmers' practice), the average Boro rice yields of S2 and S3 were 28% higher in the first year, 20% higher in the second year and 14% higher in the third year. Among the years and across scenarios, the rice yields of Boro were higher in the first year than in the second and third years by 0.2–0.7 Mg ha^{-1} and 0.2–0.4 Mg ha^{-1}, respectively, which was likely related to the low solar radiation in the second and third years compared to the first year

3.2.2.Maize or Mungbam (rice equivalent)

In scenario 4, maize was planted as a relay crop with potato in the first and second years, and Mungbam was planted after the harvest of potato in the third year. In the first year, maize produced good yield but, in the second year, maize plants suffered at 85–91 days after planting (DAP) because of waterlogging from heavy rain- fall, resulting in no harvest. In the second year, total rainfall during 85–91 DAP of maize was 5.6 times higher than in the first year. Maize and its REY were 9.2 Mg ha^{-1} and 5.2 Mg ha^{-1}, respectively, in the first year, and of Mungbam and its REY were 0.7 Mg ha^{-1} and 2.1 Mg ha^{-1}, respectively, in the third year (Table 7). Normally, farmers leave fields fallow between the two main crops (Boro and Aman) because of the uncertainty associated with rainfall as experienced in our study in the second year when maize failed because of excess rainfall in April. Therefore, we shifted to Mungbam, a shorter-duration crop (70 d), which allowed planting in February and harvesting by early April when rainfall is normally negligible.

3.2.3.Cropping system

A **cereal-based cropping system** refers to an agricultural approach where cereal crops, such as wheat, rice, maize, barley, or sorghum, serve as the primary crops in a rotation or intercropping system. This system plays a critical role in global food security by providing staple foods for millions of people while supporting sustainable agriculture. some risk of growing potato instead of Boro rice. Selection of suitable non-rice crops which can fit in the agricultural environment as well in existing market scenarios during Boro and summer seasons is important to maximize the benefits.

3.3.Water application and water productivity

3.3.1.Water application

In general, the Boro season received insufficient rainfall during December to March (8 mm in the first year, 122 mm in the second year and 13 mm in the third year) and largely depended on irrigation. Irrigation water application varied from 578 to 1247 mm to rice in S1–S3 and from 120 to 202 mm to potato in S4 across years. Irrigation input to Boro was highest in the first year, which declined by 373–520 mm across S1–S3 in the third year. Although the time trend of total input (irrigation + rainfall) was similar in three years in Boro, a gradual reduction in input from the first year to the third year was due to higher total rainfall (average of 200 mm per year) in the latter two years. The irrigation water applied in S2 and S3 was similar, suggesting that avoiding tillage did not result in any more water savings than that of puddling or wet tillage. However, this may change with time because of expected changes in soil percolation associated with changes in soil physical condition (Jat et al., 2009). On average, S2 and S3 had 18–27% lower irrigation inputs than S1 across three years, with significant differences in the second and third years. Substitution of Boro rice with potato in S4 reduced water input by an average of 6-fold (780 mm). Aman rice, which is primarily rainfed, obtained much of its water requirement from rain, which ranged from 474 to 1006 mm in three years (Table 6). Although the first year had lower rainfall than the second year during Aman, no irrigation input was required due to a favorable rainfall pattern (Fig. 1). Despite higher total rainfall in the second year than in the first year, the second year required irrigation input in all scenarios, ranging from 56 to 111 mm. In Aman year 3, the rainfall was lowest of three years but it was fairly spread across the season (Fig. 1).

The majority of water input to the fields in Boro was irrigation, while in Aman rainfall was the dominant source of water input. Fur- ther, the results demonstrated that BMPs and CA (S2–S4) resulted in significant reduction in irrigation water inputs.

3.3.2.Water productivity

In all three years, the WP_I of potato (as REY) (4.9–7.1 kg m^{-3}) in S4 was 6–12 times higher than that of Boro rice in S1–S3 (Table 9). The WP_I of Boro rice in S1–S3 (0.4–1.0 kg m^{-3}) was similar in the first and third years, and, in the second year, it was similar in S2 and S3. In year 2, WP_I of S2 and S3, was 1.0 compared to 0.6 WP_I of S1. The WP_I of the cropping system in S1–S3 was similar (0.8–1.7 kg m^{-3}) but significantly lower than that of S4 in first and third years (5.6–12.9 kg m^{-3}).

The WP_{I+R} of Boro rice in S1–S3 was similar (0.4–0.7 kg m^{-3}) and significantly lower than that of potato (3.9–6.4 kg m^{-3} as REY) in S4 across years. The WP_{I+R} of the cropping systems in S2 and S3 (0.5–0.7 kg m^{-3}) was always similar but significantly higher than in S1 by 0.1–0.2 kg m^{-3} and lower than in S4 by 0.4–1.2 kg m^{-3}.

3.4.Economic analysis

The TVCs of Boro in S1–S3 were similar and were US$1078–1134 ha^{-1}, US$1001–1064 ha^{-1} and US$908–928 ha^{-1} in the first, second and third year, respectively, which were significantly lower than those of potato (US$2030–US$2400) in S4 (Table 10). On average of three years, S4 had 123% higher TVCs than S1–S3, which was largely due to the 18–33 times higher cost of potato seed compared with rice and associated increases in fertilizer inputs.

This was likely because of the increased fertilizer and crop establishment costs in the first and second year and increased fertilizer, crop establishment and insect and disease control costs in the third year. Despite similar fertilizer costs in S2 and S3, the TVCs of S3 were always lower than in S2 because of the lower crop establishment cost in S3 resulting from machine transplanting. The TVCs of maize in S4 were US$808 ha^{-1} in year 1, US$341 ha^{-1} in year 2. In year 2, though maize failed, it incurred US$341 ha^{-1} TVCs. On a system basis, across years, S4 had the highest TVCs, ranging from US$3068 to US$4059 ha^{-1}, which is largely driven by the higher cost of potato cultivation. In year 1

The GRs, NRs and BCR of three years were averaged because of non-significant year-by-scenario interactions. Despite the highest costs, GRs were also the highest in S4 because of high potato yield and economic value as a cash crop. Gross returns in S4 were US$1167–1442 ha^{-1} higher than those of S1–3. Gross returns of Boro rice in S2 and S3 were similar but they were 20–22% higher than in S1. Gross returns of Aman rice were 39%, 34% and 25% higher in S2, S3 and

S4, respectively, than in S1. These differences among scenarios were largely due to differences in yields. On a system basis, S1 had the lowest GRs of US$2312 ha^{-1}, US$2128 ha^{-1} and US$1882 ha^{-1} in the first, second and third years, respectively.

The results of economic analysis of different scenarios across years suggest that the integration of BMP and CA in farmers' management practices is a potential option to increase the economic returns of the rice–rice system by 1.8–3.0 times than those of the farmers' practice with a BCR of 1.3–1.5. Similar economic returns have been reported from rice–wheat rotations on Northwestern and Eastern IGP of India (Ghazala et al., 2013; Laik et al., 2014)

3.5.Energy inputs and efficiency

Total energy inputs across years and scenarios in Boro rice and potato (24,679 MJ ha^{-1} to 35,834 MJ ha^{-1}) were generally twice to that in Aman rice (10,056 MJ ha^{-1} to 24,010 MJ ha^{-1}).In Boro rice, input energy was similar in the four scenarios in the first year but differed significantly in the second and third years. Compared with S1, it was 14% and 7% lower in S3 but 5% and 6% higher in S4 in the second and third years, respectively. The lower energy uses in S3 were largely due to reduced tillage and the higher uses in S4 were because of potato requiring relatively more energy in seed, fertilizer and labor. By contrast, the energy inputs in Aman rice varied among scenarios in all years, and were higher in S3 than in S1, S2 and S4 by

75%, 8% and 55%, respectively, in the first year; and by 86%, 36% and 77%, respectively, in the second year. In the third year, S3 was similar to S2 but higher than S1 and S4 by 62% and 7%, respectively. The higher energy use in S3 in Aman rice was largely due to machine transplanting and associated fuel cost. On a systems basis, S4 had the highest energy use in the first and third year, and in the second year this was highest in S3. Energy used for the system in S4 (53,650 MJ ha^{-1}) was 15% higher than in S1 and similar to that in S2 and S3 in the first year. In the third year, energy use in S4 (44,925 MJ ha^{-1}) was 21% higher than in S1, and 9% higher than in both S2 and S3. In the second year, the energy used for the system in S3 (49,544 MJ ha^{-1}) was 16% more than in S1 but 6% and 10% more than in S2 and S4, respectively.

4.General discussion

We tried transplanting under non-puddled (reduced tillage) conditions in S3. However, neither rice yields nor input usages differed between S2 and S3, suggesting that reduced tillage was not adequate enough to make large changes in yield and input usages, at least in the first three years. On the other hand, crop diversification, reduced tillage, and partial residue mulch in S4 resulted in significantly higher system performance. Compared to S1, annual crop productivity increased by 3.2–10.6 Mg ha^{-1}, total water productivity by 0.6–1.3 kg grain m^{-3} water and economic returns by US$331–1090 ha^{-1}. The energy balance was also highly positive as shown by significantly lower (2.1–3.3 MJ kg^{-1} ha^{-1}) specific energy in S4. This clearly demonstrates the role of crop

diversification in the E-IGP of Bangladesh. However, the selection of an alternative crop is crucial. There are important considerations such as rainfall pattern, and price volatility of the produce. Our research highlights the need of more longer-term cropping systems research to identify compatible alternative crops to increase farmers' profitability while preserving the resource base. There is also a need for breeding and selection of a rice plant type suitable for direct seeding after zero tillage in heavy-textured soils.

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References

Acemoglu, M., Aksoy, A.S., 2005. The cultivation and energy balance of *Miscanthus giganteus* production in Turkey. Biomass Bioenergy 29, 42–48.

Argiro, V., Stamatas, A., George, D., Nanos, A., Constantinos, A., 2006. Energy flow for integrated apple production in Greece. Agric. Ecosystem. Environ.

Bala, B.K., Hussain, M.D., 1992. Energy use pattern for crop production in

Bangladesh.
J. Eng. Int. Dev. 1, 41–47.

BRRI, 2010. Annual Internal Review Report for 2009–10. Bangladesh Rice Research Institute, Gazipur, Bangladesh.

BRRI, 2007. Aphonic Daner Chas (A Bengali Publication). Bangladesh Rice Research Institute, Gazipur, Bangladesh.

BARI, 2004. Krishi Prajakta Harbai (A Bengali Publication). Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

Binning, A.S., Pathak, B.S., Panesar, 1983. The Energy Audit of Crop Production System Research Report. School of Energy Studies for Agriculture, Punjab Agricultural University, Ludhiana, Punjab, India.

Bouzoukis, G.J., 1962. Hydrometer method improved for making particle size anal-ysis of soils. Agron. J. 54, 464–465.

Bray, H.R., Kurtz, L.T., 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. 59, 39–45.

Caracci, M., Topock, M., Akinci, I., Omari, A., 2005. Energy use pattern of some field crops and vegetable production: case study for Antalya region, Turkey. Energy Convers. Manage. 46, 655–666.

Erdal, G., Segun, K., Erdal, H., Gunduz, O., 2007. Energy use and economic analysis of sugar beet production in Toklat province of Turkey. Energy 32, 35–41.

Sangun, K., Gunduz, O., Erdal, G., 2007. Input–output energy analysis in dry apricot production of Turkey. Energy Convers. Manage. 48, 592–598.

FAO, 2012. FAOSTAT. Food and Agriculture Organization of the United Nations—For a World Without Hunger. Statistics Division. FAO, (http://faostat.fao.org/⟩.

Gumma, M.K., Nelson, A., Maunahan, A., Thinkably, P.S., Islam, S., 2012. Rice crop- ping patterns in Bangladesh. Rice Today. Jan–Mar. Vol. 11, No. 1. International Rice Research Institute (IRRI), Los Ban˜os, Philippines.

Goshala, M.K., Virender, K., Sharma, P.C., Saharawi, Y.S., Jat, H.S., Singh, M., Kumar, A., Jat, M.L., Humphreys, E., Sharma, D.K., Sharma, S., Ladha, J.K., 2013. Optimizing intensive cereal-based cropping systems addressing current and future drivers of agricultural change in the northwestern Indo-Gangetic Plains of India. Agric. Ecosyst. Environ. 177, 85–97.

Gopalan, C., Sastri, B.V.R., Balasubramaniam, S.C., 1978. Nutritive Value of Indian Foods. National Institute of Nutrition, ICMR, Hyderabad, India.