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The Assessment of Four Crop-Based Cropping System Productivity, Nutrient Uptake and Soil Fertility With Existing Cropping Systems

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Abstract

Sustainable crop production through intensification of crops in cropping system is a global important issue to ensure food security, human and soil nutrition, poverty alleviation, and job opportunity creation. Rabi crop (mustard/lentil)-Jute cropping system and transplanted (T) Aman rice-Boro (T. Boro) rice cropping system are the traditional cropping systems in Low Ganges River Floodplain (AEZ-12) soils of Bangladesh. Jute and T. Aman rice are usually cultivated in summer season, but the T. Boro rice is cultivated in winter season. Jute and T. Boro rice are highly cost consuming crops due to need more irrigation, labors and fertilizer etc. T. Boro rice and jute are easily replaced by a short duration of mungbean and T. Aus rice in the existing cropping system. Hence field trial on different cropping systems were conducted in Regional pulses Research Station (RPRS), BARI, Madaripur and the adjacent farmers' field of RPRS during 2013-14 and 2014-15 to compare and evaluate the four crop-based cropping systems with existing cropping systems based on system productivity, nutrient uptake and balance, profitability and sustaining soil fertility. The experiment was planned with six treatments comprising three of four crop-based cropping systems and three existing traditional cropping systems. The treatments were FCS_1 (Mustard-Mungbean-T. Aus rice-T. Aman rice), FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice), FCS_3 (Fieldpea-Mungbean-T. Aus rice-T. Aman rice), ECS_1 (Mustard-Jute), ECS_2 (Lentil-Jute) and ECS_3 (T. Boro rice-T. Aman rice) following randomized complete block design with three dispersed replications. As per results, the greater system productivity (rice equivalent yield: 16368 kg ha^{-1}) was significantly obtained from FCS_2 than the other system treatments. The FCS_2 treatment exhibited the highest percent increment of rice equivalent yield (REY) over existing cropping system ECS_1, ECS_2 and ECS_3 was 322%, 234% and 84.1%, respectively. Also higher %REY increment of FCS_2 was 20.3% and 14.5% over the other four crop-based cropping systems FCS_1 and FCS_3. Production efficiency was highest in same FCS_2 treatment. Land use efficiency increment was observed higher in Fieldpea-Mungbean-T. Aus rice-T. Aman rice cropping system. Total nutrient (N, P, K, S, Zn, B) uptakes and nutrient balance were positively influenced among the cropping systems, but both were showed inconsistent trends. The result of postharvest soil exhibited higher organic carbon (8.78 g kg^{-1}) and total N content (0.74 g kg^{-1}) was in FCS_2 treatment. The FCS_2 was also economically profitable and viable as compared to other cropping systems due to having higher gross return, gross margin and benefit cost ratio (2.48). The FCS_3 was the second economically profitable and viable system as compared to other cropping systems. Intensification and diversification of crops from two to four crop-based cropping systems lead to increase the system productivity, profitability, and sustaining soil fertility. Results suggest that lentil-Mungbean-T. Aus rice-T. Aman rice followed by Fieldpea-Mungbean-T. Aus rice-T. Aman rice cropping system can practice in the experimental area for positive change the farmers' livelihoods. This finding may be potential for the area where there is no practice of improving four crop-based cropping systems.

Keywords: four crop-based system, rice equivalent yield, nutrient uptake, economics, food and nutrition security

1. Introduction

Bangladesh is an over populated (density about 1237 persons per sq. km.) country that needs more food, nutritional security, and construction of houses (Hossain et al., 2018). Total cultivable land of Bangladesh is 8.5

million hectares, decreasing 1% every year used as non-agriculture (Barman et al., 2019; Rahman et al., 2018). Very little scope in Bangladesh is increasing the cultivable land horizontally but some scope is increasing vertically like cropping intensity augmented from 191 to 400% by improving the existing cropping systems with incorporation of short duration crops viz. lentil, mustard, field pea, mungbean, T. Aus and T. Aman rice (Mondal et al., 2015). Sustainable crop production in Bangladesh through intensification and diversification of crops in the cropping system is considered gradually important in national issues like food security, human and soil nutrition, poverty mitigation, and job opportunity creation (Ahmed et al., 2019; Rahman et al., 2018). New millennium key challenge is increasing 50% yield per unit area by manipulating the limited resources of land to ensure food and nutrition (Hossain et al., 2018). In order to produce more food within a limited area, the most important options are i) to increase the cropping intensity producing four or more crops over the same piece of land in a year and ii) to increase the production efficiency of the individual crop by using optimum management practices (Rahman et al., 2020). However, four crops legume-based cropping systems are the ways without deterioration of soil fertility, improving food and nutritional security, and changing rural livelihoods (FAO, 2017).

Rice, mustard and legumes (lentil, mungbean, fieldpea) are promising crops of Bangladesh where rice is staple food for the people. Legumes are the vital source of protein and minerals (Faris et al., 2013) and also used as fodder for farm animal. Legumes help to enhance the soil fertility through biological nitrogen fixation (Howlader et al., 2020; Miah et al. 2005). Jute is the major cash crops in greater Faridpur region covers almost 60 to 77 thousand hectares of land (Ahmed et al., 2019). But farmers of this region face different problems for jute cultivation like getting lower market price, unavailability of water in the time of jute rotting, poor quality seed, and pest attack. In this context mungbean is easily be introduced after harvest of Rabi crops replacing the jute. Currently legume and oil seed crops cultivation are at decreasing position in Madaripur region of Bangldesh in Rabi season due to widely cultivation of Boro rice. The unit price of legume and mustard crops are comparatively higher than that of unit price of rice. But rising population is essential to fulfill the rice demand through producing the high yielding short duration variety of T. Aus and T. Aman rice. However, mustard, lentil and field pea could be introduced in Rabi season replacing Boro rice, mungbean could be introduced after the harvest of mustard/lentil/field pea in February replacing jute and Boro rice. Then T.Aus rice (var. BRRI dhan 48) could easily be transplanted in the 2nd week of May after 1st picking of Mungbean. Then T. Aman rice (var. BRRIdhan 62) could be transplanted in the 3rd week of August and thus harvested within last week of October. Hence, Mustard-Mungbean-T. Aus rice-T. Aman rice, Lentil-Mungbean-T. Aus rice-T. Aman rice and Field pea-Mungbean-T. Aus rice-T.Aman rice could be developed as an alternate four crop-based cropping system to increase the productivity and maintain soil fertility. However, adoption of high yielding variety legume and oilseed crops in the farm levels in the rice-based cropping system has generated a big socio-economic impact through creating employment opportunity (Rahman et al., 2018). So, information should need to update of different four crop-based cropping systems through assessing the productivity, production efficiency, land use efficiency, nutrient uptake and soil fertility for policy maker and donor agencies. The study was therefore undertaken to find out the performance of the alternate four crop-based cropping systems with existing traditional cropping systems for increasing the cropping intensity, total productivity, nutrient uptake and balance as well as farmers' income.

2. Materials and Methods

2.1 Site Description

The field experiment of four crop-based cropping systems were conducted at the farm of Regional Pulses Research Station (RPRS), Madaripur, under Bangladesh Agricultural Research Institute (BARI) and the field experiment of existing traditional cropping systems were carried out in adjacent of the RPRS farmer's field, Madaripur during 2013-14 to 2014-15 (November 2013 to October 2015). The experimental place was geographically located at 23°10′ N latitude and 90°11′ E longitude and elevated of 7.0 m above sea level. Land type of the experimental field was high and nature of the soil was calcareous and the texture was loam belonging to the Gopalpur soil series under the agro-ecological zone Low Ganges River Floodplain (AEZ-12) (Anonymous, 1975; Shil et al., 2016). Beginning the experiment, initial soil sample was collected at 0-15 cm depth from different spots of the experimental field and analyzed by standard methods. The nutrient statuses are presented in Table 1.

Table 1. Initial soil nutrient status of the experimental site

Nutrient	Soil test value		Critical level	*Soil test interpretation
	Four crops system	Existing system		
pH	7.4	7.5	-	Slightly alkaline
Organic carbon (g kg^{-1})	8.15	8.32	-	Low
Ca (meq.100g^{-1} soil)	12.8	13.2	2.0	High
Mg (meq.100g^{-1} soil)	4.5	5.1	0.5	High
K (meq.100g^{-1} soil)	0.14	0.15	0.12	Low
Total N (g kg^{-1})	0.63	0.64	1.2	Very low
Available P (mg kg^{-1})	15	16	8	Medium
Available S (mg kg^{-1})	16.2	15.9	10	Low
Available Zn (mg kg^{-1})	0.88	0.9	0.6	Low
Available B (mg kg^{-1})	0.17	0.16	0.2	Low

Note. *Anonymous (2012).

The climate of the experimental site was subtropical humid monsoon condition. It was categorized by relatively monsoon rainfall, high humidity, and high temperature during March to June. Long day with less clear sunshine, sometimes the sky remains cloudy for heavy rainfall (about 80% of the total rainfall) during June to October. The site has scanty rainfall, low humidity, low temperature, short day, and clear sunshine from October to March. Average temperature ranged from 12.0 to 38 ^oC and average annual rainfall varied from 1500 to 5500 mm around the year (Huq & Shoaib, 2013).

2.2 Cropping System Treatment, Design, Layout and Fertilizer Rate

The experiment was planned with six treatments comprising three of four crop-based cropping systems and three existing traditional cropping systems. The system treatments were FCS_1 (Mustard-Mungbean-T. Aus rice-T. Aman rice), FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice), FCS_3 (Fieldpea-Mungbean-T. Aus rice-T. Aman rice), ECS_1 (Mustard-Jute), ECS_2 (Lentil-Jute) and ECS_3 (T. Boro rice-T. Aman rice) following randomized complete block design with three dispersed replications. The experiment of four crop-based improved cropping systems was started with mustard, lentil and fieldpea. The second, third and fourth crops were mungbean, T. Aus rice and T. Aman rice, respectively. The trial of existing traditional cropping systems was started with the crop mustard, lentil and T. Boro rice. The second crops were jute and T. Aman rice. The experiments were completed round the year with two consecutive years (2013-14 to 2014-15). The unit plot size of all cropping systems was 5 × 4 m. Every crop was received the recommended doses of fertilizer according to Anonymous (2012) as N, P, K, S, Zn and B presented in the Table 2. The cowdung was applied 5 t ha^{-1} in each crop. The source of N, P, K, S, Zn and B were urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid, respectively.

Table 2. Detail fertilizers (NPKSZnB) for each crop of four crop-based cropping systems and existing traditional cropping systems

Treatment	Crop	Rate of fertilizer application (kg ha^{-1})					
		N	P	K	S	Zn	B
Four crop-based cropping systems	Mustard	100	20	60	12	2	1.5
	Lentil	20	15	30	10	2	1.5
	Field pea	20	15	30	10	2	1.5
	Mungbean	20	20	40	12	2.5	1.5
	T. Aus rice	80	10	50	7	1.5	-
	T. Aman rice	80	10	60	7	1.5	-
Existing traditional cropping systems	Mustard	100	20	60	12	2	1.5
	Lentil	20	15	30	10	2	1.5
	Jute	120	10	80	15	2.5	-
	T. Boro rice	160	20	100	15	2.5	-
	T. Aman rice	80	10	60	7	1.5	-

2.3 Agronomic Management

2.3.1 Land Preparation

The land was prepared for first crop of four crop-based improved cropping systems by 3-4 passes with a tractor driven chisel plough and leveled with tractor driven rotavator. Weeds and stubbles were removed manually. The plots were prepared for every test crop by 3-4 spading keeping the same layout. The land of existing traditional cropping system was also turn with chisel plough by 3-4 passes for first crop and leveled with tractor driven rotavator. Weeds and stubbles were cleaned manually. The plots were prepared for second crop by 3-4 spading keeping the same layout.

2.3.2 Fertilizer Application

All fertilizers except urea were applied as basal at the time of final land preparation for T. Boro rice, T. Aus and T. Aman rice. Fertilizers were manually mixed with soil carefully. Urea was applied in three equal split both T. Aus and T. Aman rice and also same in T. Boro rice where the first split was applied after seedling establishment, the second split during maximum tillering stage and the last split before panicle initiation. Regarding mustard, full dose of all fertilizers including half of urea were applied as basal at the time of final plot preparation. Remaining half urea was applied as top dress at flowering stage. In case of Jute, full dose of all fertilizers except urea were applied as basal at the time of final land preparation. Urea was applied in three equal split where the first split was applied during final land preparation, second split was applied at 20 DAS and final split was applied at 40 DAS. In case of lentil, fieldpea and mungbean, full dose of all fertilizers were applied during the final land preparation. Fertilizers were manually mixed with soil appropriately.

2.3.3 Seed Sowing/Seedling Transplanting and Harvesting

Quality seeds of mustard (cv. BARI Sarisa-14), lentil (cv. BARI Masur-7), field pea (cv. BARI Fieldpea-1), mungbea (cv. BARI Mung-6) and jute (cv. Local Tosha) were treated with Provax 200 WP fungicide at 2.0-2.5 g kg^{-1}. The seeds of all test crops of improved four crop-based cropping systems were sown maintaining the different plant spacing presented in Table 3. Seeds of mustard, lentil and jute in traditional cropping systems were sown as broadcasting (Table 3). Thirty-day-old healthy seedlings of T. Aus rice (cv. BRRI dhan 48) and T. Aman rice (cv. BRRI dhan 62) and healthy seedlings (38-39 days old) of Boro rice (cv. BRRI dhan 29) were transplanted manually maintaining the plant spacing 20 cm ×15 cm presented in Table 3. The 2-3 seedlings of all rice crops (T. Aus rice, T. Aman rice and T. Boro rice) were transplanted in each hill. The crop wise seed rate was presented in Table 3. After maturity every crop was harvested according to Table 3.

Table 3. Details of seed sowing/seedling transplanting and harvesting time, seed rate and spacing for crops of different cropping systems in field trail

Treatment	Crop and variety	Seed rate	Spacing	Date of seed sowing/ seedling transplanting	Date of harvesting
Four crop-based cropping systems	Mustard (BARI Sarisa-14)	6 kg ha^{-1}	30 cm× 10 cm	10-12 November	28-30 January
	Lentil (BARI Masur-7)	35 kg ha^{-1}	30 cm× continuous	12-13 November	01-02 March
	Field pea (BARI Fieldpea-1)	35 kg ha^{-1}	30 cm× continuous	10 November	26 February
	Mungbean (BARI Mung-6)	35 kg ha^{-1}	30 cm× 10 cm	05 February for FCS_1 05-07 March for FCS_2 01March for FCS_3	11 April for FCS_1 09-11May for FCS_2 05May for FCS_3
	T. Aus rice (BRRI dhan 48)	30 kg ha^{-1}	20 cm ×15 cm	18-19 April for FCS_1 16-18 May for FCS_2 11 May for FCS_3	10-11 July for FCS_1 05-08August for FCS_2 31July for FCS_3
	T. Aman rice (BRRI dhan 62)	30 kg ha^{-1}	20 cm ×15 cm	17July for FCS_1 12-14August for FCS_2 05August for FCS_3	10 October for FCS_1 02-05November for FCS_2 30 October for FCS_3
Existing traditional cropping systems	Mustard (BARI Sarisa-14)	7 kg ha^{-1}	Broadcasting	10-12 November	30-31 January
	Lentil (BARI Masur-7)	40 kg ha^{-1}	Broadcasting	13-14 November	02-03 March
	Jute (Local Tosha)	8 kg ha^{-1}	Broadcasting	16-17 April for ECS_1 and ECS_2	07-09 August for ECS_1 and ECS_2
	Boro rice (BRRI dhan 29)	30 kg ha^{-1}	20 cm ×15 cm	15 January	16 May
	T. Aman rice (BRRI dhan 62)	30 kg ha^{-1}	20 cm ×15 cm	10 July	05 October

Note. FCS = Four crop-based cropping system: FCS_1 = Mustard-Mungbean-T. Aus rice-T. Aman rice cropping system; FCS_2 = Lentil-Mungbean-T. Aus rice-T. Aman rice cropping system; FCS_3 = Fieldpea-Mungbean-T. Aus rice-T. Aman rice cropping system. ECS = Existing traditional cropping system: ECS_1 = Mustard-Jute-Fallow cropping system; ECS_2 = Lentil-Jute-Fallow cropping system; ECS_3 = T. Boro rice-T. Aman rice-Fallow cropping system.

2.3.4 Plant Protection and Intercultural Operation

Weeding was done for mustard at 20 and 35 days after sowing (DAS). Irrigation was provided at 22 DAS and at bearing stage. Insecticide Karate 2.5 EC at the rate of 2 ml L^{-1} water was sprayed two times before flowering and during the pod setting stage to reduce the infestation of aphid and pod borer. In case of lentil, weeding was done at 25 DAS and 55 DAS. The *Stemphylium* blight disease of lentil was controlled by spraying of Rovral® at 2 g L^{-1} with three times interval of 10 days, started at flowering stage. The infestation of Pod borer and aphids were controlled by spraying the insecticide Karate 2.5 EC at 2 ml L^{-1} two times at podding stage interval of 10 days. Irrigation was not applied in lentil. Weeding of field pea was done at 30 DAS. Weeding of mungbean was done at 15 and 40 DAS. The mungbean was infested by thrips and pod borer which was well controlled by application of Karate 2.5 EC at 2 ml L^{-1}. Single irrigation was applied before seed sowing of mungbean. In case of jute, T. Aus rice, T. Aman and T. Boro rice, weeding was done manually as required throughout the growing season of the crops. Insect and diseases were controlled properly as and when required. Irrigations were applied as per the requirement of the respective jute, T. Aus rice, T. Aman rice and T. Boro rice crop.

2.3.5 Data Collection

(1) Yields of All Crops

Matured Aus rice, Boro rice and Aman rice was harvested from each plot and bundled separately. It was brought to the threshing floor and threshed plot-wise. Separated grain of each plot was sun-dried. Data on grain yield (kg ha^{-1}) of all rice crops were recorded after adjusting around 14% moisture content. Matured above ground plants of all rice from 1 m^2 of each plot were harvested and sundried for calculating straw yield at kg ha^{-1}. Seed (kg ha^{-1}) and stover/straw yield (kg ha^{-1}) of mustard, lentil and field pea were measured based on the whole plot technique. Matured plants of each plot were harvested and brought to the threshing floor for sun drying and seeds were separated with the help of a bamboo stick. The sun-dried stovers were weighed and converted it into kg ha^{-1}. Plot wise grand total seeds were sun-dried and adjusted to moisture content around 10% based on the value of actual moisture measured by digital seed moisture tester manual (Seedburo 1200D Digital Moisture Tester Manual, USA). Matured pods of mungbean were detached from every plot and brought to the threshing floor for sun drying and seeds were separated with the help of a bamboo stick. Plot-wise total seeds of the whole plot were cleaned and sun-dried adjusted at around 10% moisture level measured by digital seed moisture tester manual (Seedburo 1200D Digital Moisture Tester Manual, USA) and then weighed and converted it into kg ha^{-1}. Matured above ground parts of mungbean from 1 m^2 of each plot were harvested and sun-dried. The dried stovers were weighed and converted it into kg ha^{-1}. Jute fiber yield (kg ha^{-1}) was recorded on the basis of whole plot technique. The rice equivalent yield (REY) was measured as the yield of individual non-rice crop multiplied by the market price of that crop divided by the market price of rice using the following equation (Vandana et al., 2014).

$$REY = \frac{Yield\ of\ idividual\ non\ rice\ crop \times Market\ price\ of\ that\ crop}{Market\ price\ of\ rice} \quad (1)$$

Where, *REY* is the rice equivalent yield, the yield of individual non-rice crop (kg ha^{-1}) and the market price of rice crop (BDT kg^{-1}) and the market price of non-rice crop (BDT kg^{-1}).

Land use efficiency was estimated by the total duration of crops in the sequence divided by 365 days and expressed in % as outlined by Tomar and Tiwari (1990).

Production efficiency (PE) was calculated as the ratio of the total system productivity in terms of rice yield equivalent in kg ha^{-1} to the total duration of the system in days (Tomar & Tiwari, 1990).

(2) Soil and Plant Samples Analysis

Soil samples at 0-15 cm were collected from each treatment plot after completion of two cycles of all cropping systems. Plant samples (straw/stovers and grain/seed) against each treatment plot were oven-dried at 70 °C for 48 h and finely ground. The initial and final soil samples were analyzed for determination of soil pH and organic carbon outlined by Page et al. (1982); total N by Microkjeldahl method (Page et al., 1982); Available P was determined by Olsen method (Page et al., 1982); Exchangeable Ca and Mg was extracted with a solution 1 M NH_4OAc as described by Gupta (2004). Content of Ca and Mg in the extract was measured by Atomic Absorption Spectrophotometer (Varian, Model SpectrAA 55B, Sydney, Australia); exchangeable K by 1N NH4OAc method (Jackson, 1973); available S by turbidity method using $BaCl_2$ (Fox et al., 1964); available Zn by DTPA method (Lindsay & Norvell, 1978); available B by azomethine-H method (Page et al., 1982).

Ground plant samples were digested with di-acid mixture (HNO_3-$HClO_4$) (5:1) as described by Piper (1964) for the determination-concentration of N (Micro-Kjeldahl method), P (spectrophotometer method), K (atomic absorption spectrophotometer method), S (turbidity method using $BaCl_2$ by spectrophotometer), Zn (atomic absorption spectrophotometer method) and B (spectrophotometer following azomethine-H method).

(3) Nutrient Uptake and Apparent Balance Calculation

Crop nutrient uptake was calculated from the system crop yields (seed/grain and stover/straw) and nutrient (N, P, K, S, Zn and B) content in seed/grain and stover/straw of crops (Anonymous, 2012). Apparent nutrient balances for all the copping systems (average of two years) were computed as the difference between nutrient input and output of the system (Anonymous, 2012). The inputs were supplied from fertilizer and the outputs were estimated from crop uptake in a cycle.

2.3.6 Statistical Analysis

Collected data were subjected to analyze by statistical software Statistix-10 (Statistix-10, 1985). The means of all data were compared using the least significant difference (LSD) test at a significant level of $p \leq 0.05$.

2.3.7 Cost and Return Analysis

The benefit cost ratio (BCR) was calculated for a hectare of land. Management costs were calculated by adding the cost acquired from labor, plowing, irrigation and inputs of all test crops for each cropping system. Grain yield of T. Aus, T. Aman, and Boro rice, seed yield of mustard, lentil, and mungbean and fiber yield of jute was utilized to calculate gross return. Shadow prices (land rent and others) were not considered. Gross return was measured by multiplying all test crops' grain/seed/fiber yield by unit price (farm gate). Gross margin was calculated by subtracting management cost from gross return.

3. Results

3.1 Yields of Crops

Result revealed that the average seed/grain yield of mustard, mungbean, T. Aus and T. Aman rice for FCS_1 (Mustard-Mungbean-T. Aus rice-T. Aman rice) were recorded 1533, 998, 4055 and 4011 kg ha^{-1}, respectively (Table 4). The FCS_2 treatment (Lentil-Mungbean-T. Aus rice-T. Aman rice) having the mean seed/grain yield 1273, 1095, 4314 and 4041 kg ha^{-1}, respectively for lentil, mungbean, T. aus and T. aman rice. The mean seed/grain yield of fieldpea, mungbean, T. Aus and T. Aman rice under FCS_3 (Fieldpea-Mungbean-T. Aus rice-T. Aman rice) was obtained 1412, 988, 4272 and 3986 kg ha^{-1}, respectively. Among the four crop-based cropping systems, the FCS_2 showed the best performance in individual crop yield. Results of all four crop-based cropping systems indicated the yield of T. Aus rice was observed better than the other cereal crop that improvement might be legumes residues incorporation in soil. The mean straw/stover yield of all test crops of FCS_1, FCS_2 and FCS_3 cropping systems presented in Table 4 where the crops under FCS_2 like lentil, mungbean, T. Aus and T. Aman rice were exhibited best stover/straw yield.

Table 4. Yields of individual crop under Mustard-Mungbean-T.Aus rice-T.Aman rice, Lentil-Mungbean-T.Aus rice-T.Aman rice and Fieldpea-Mungbean-T.Aus rice-T.Aman rice cropping system during 2013-14 (Year1) and 2014-15 (Year2)

Cropping system	Seed yield (kg ha^{-1})			Straw/stover yield (kg ha^{-1})			Seed yield (kg ha^{-1})			Straw/stover yield (kg ha^{-1})		
	1st crops (Mustard/Lentil/Fieldpea)						2nd crop (Mungbean)					
	Year1	Year2	Mean	Year1	Year2	Mean	Year1	Year2	Mean	Year1	Year2	Mean
FCS_1	1512	1554	1533	3324a	3410a	3367	974ab	1021	998	1934b	2137	2036
FCS_2	1246	1300	1273	1455b	1533b	1494	1089a	1100	1095	2257a	2363	2310
FCS_3	1392	1431	1412	1567b	1688b	1628	952b	1023	988	1789b	2176	1983
CV (%)	11.1	9.04	-	7.84	6.07	-	5.82	11.5	-	6.97	5.34	
$LSD_{0.05}$	ns	ns	-	375	304	-	132	ns	-	315	ns	
Cropping system	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	3rd crop (T. Aus rice)						4th crop (T. Aman rice)					
	Year1	Year2	Mean	Year1	Year2	Mean	Year1	Year2	Mean	Year1	Year2	Mean
FCS_1	3897b	4212	4055	4012b	4333	4173	4099	3923	4011	4179	4045	4112
FCS_2	4332a	4296	4314	4422a	4412	4417	3960	4122	4041	4061	4244	4153
FCS_3	4198a	4346	4272	4311ab	4488	4400	4075	3897	3986	4207	4034	4121
CV (%)	2.73	2.22		3.49	3.35		3.38	3.92		3.44	3.36	
$LSD_{0.05}$	256	ns		336	ns		ns	ns		ns	ns	

Note. FCS = Four crop-based cropping system: FCS_1 = Mustard-Mungbean-T. Aus rice-T. Aman rice; FCS_2 = Lentil-Mungbean-T. Aus rice-T. Aman rice; FCS_3 = Fieldpea-Mungbean-T. Aus rice-T. Aman rice.

Values within columns followed by the same letter are not significantly different according to the least significant difference (LSD) test at $p \leq 0.05$.

The crop yield of existing traditional cropping system was shown significant (Table 5). The mean seed yield of mustard and fiber yield of jute under ECS_1 was found 1493 and 1638 kg ha^{-1}, respectively (Table 5). In case of ECS_2, the average seed yield of lentil and fiber yield of jute was 914 and 1695 kg ha^{-1}, respectively (Table 5). In the study, the ECS_3 having the mean grain yield of T. Boro rice and T. Aman rice was 5073 and 1817 kg ha^{-1}, respectively. The mean straw yield of mustard and dry plant yield of jute under ECS_1 were recorded 2802 and 8617 kg ha^{-1}, respectively (Table 5). Regarding ECS_2, the average stover yield of lentil and dry plant yield of jute were found 1166 and 9961 kg ha^{-1}, respectively. The mean straw yield of T. Boro rice and T. Aman rice under ECS_3 was found 5206 and 3931 kg ha^{-1}, respectively (Table 5).

Table 5. Yields of individual crop under existing different cropping system during 2013-14 (Year1) and 2014-15 (Year2)

Cropping system	Seed/grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Fiber/grain yield (kg ha^{-1})			Dry plant/Straw yield (kg ha^{-1})		
	1st crops (Mustard/Lentil/T. Boro rice)						2nd crop (Jute/T. Aman rice)					
	Year1	Year2	Mean	Year1	Year2	Mean	Year1	Year2	Mean	Year1	Year2	Mean
ECS_1	1474b	1511b	1493	2735b	2869b	2802	1600b	1675b	1638	8000b	9234a	8617
ECS_2	900c	927c	914	1123c	1209c	1166	1712b	1678b	1695	10576a	9345a	9961
ECS_3	5012a	5134a	5073	5163a	5248a	5206	3875a	3759a	3817	3965c	3897b	3931
CV (%)	4.52	3.44	-	3.69	3.78	-	4.72	5.37	-	7.34	10.2	-
$LSD_{0.05}$	248	194	-	251	266	-	256	288	-	1249	1738	-

Note. ECS = Existing traditional cropping system: ECS_1 = Mustard-Jute-Fallow; ECS_2 = Lentil-Jute-Fallow, ECS_3 = T. Boro rice-T. Aman rice-Fallow.

Values within columns followed by the same letter are not significantly different according to the least significant difference (LSD) test at $p \leq 0.05$.

3.2 Rice Equivalent Yield, System Duration, Land Use Efficiency and Production Efficiency

Total productivity of different cropping systems was assessed in terms of rice equivalent yield (REY) and it was calculated from the yield of component crops. Rice equivalent yield was varied significantly among the different cropping systems (Figure 1). The system REY of FCS_1, FCS_2, FCS_3, ECS_1, ECS_2 and ECS_3 were 13608, 16368, 14293, 3878, 4894 and 8890 $kg{\cdot}ha^{-1}{\cdot}year^{-1}$, respectively. The highest REY (16368 $kg{\cdot}ha^{-1}{\cdot}year^{-1}$) was obtained from FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice) treatment showed significantly different with the other treatments. The lowest REY was from ECS_1 (Mustard-Jute) treatment (Figure 1). Percent rice equivalent yield increment of FCS_1, FCS_2 and FCS_3 over existing ECS_1 (Mustard-Jute) was recorded 251%, 322% and 268%, respectively (Figure 2a). The percent rice equivalent yield increment of FCS_1, FCS_2 and FCS_3 over existing ECS_2 (Lentil-Jute) was observed 178%, 234% and 192%, respectively (Figure 2b). Similarly, the percent REY increment of FCS_1, FCS_2 and FCS_3 over existing ECS_3 (T. Boro rice-T. Aman rice) was calculated 53.1%, 84.1% and 60.8%, respectively (Figure 2c). The percent increment indicated the FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice) system performed better than the other four crop-based cropping systems.

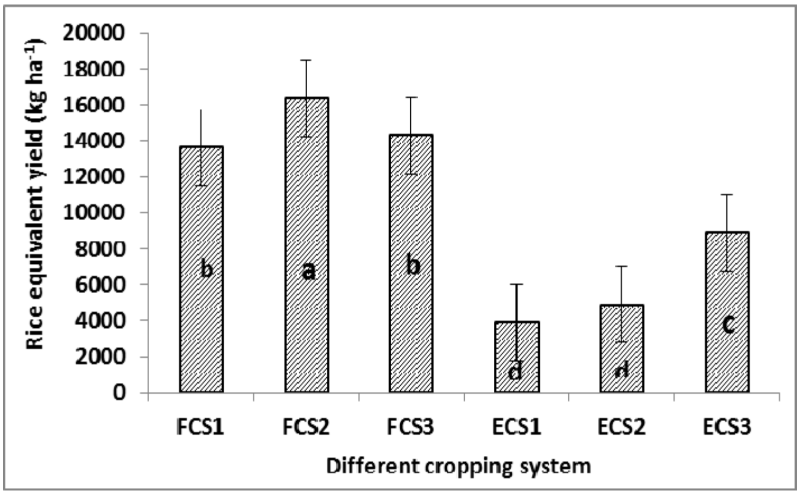

Figure 1. Rice equivalent yield under different cropping systems (mean data of two years)

Note. FCS = Four crop-based cropping system: FCS_1 = Mustard-Mungbean-T. Aus rice-T. Aman rice; FCS_2 = Lentil-Mungbean-T. Aus rice-T. Aman rice; FCS_3 = Fieldpea-Mungbean-T. Aus rice-T. Aman rice. ECS = Existing traditional cropping system: ECS_1 = Mustard-Jute-Fallow; ECS_2 = Lentil-Jute-Fallow; ECS_3 = T. Boro rice-T. Aman rice-Fallow.

Values followed by the same letter are not significantly different according to the least significant difference (LSD) test at $p \leq 0.05$.

Price of output: Aus rice = BDT 20 kg^{-1}, Boro rice = BDT 20 kg^{-1}, Aman rice = BDT 20 kg^{-1}, Jute = BDT 20 kg^{-1}, Mustard = BDT 30 kg^{-1}, Lentil = BDT 70 kg^{-1}, Mungbean = BDT 65 kg^{-1}, Fieldpea = BDT 40 kg^{-1}.

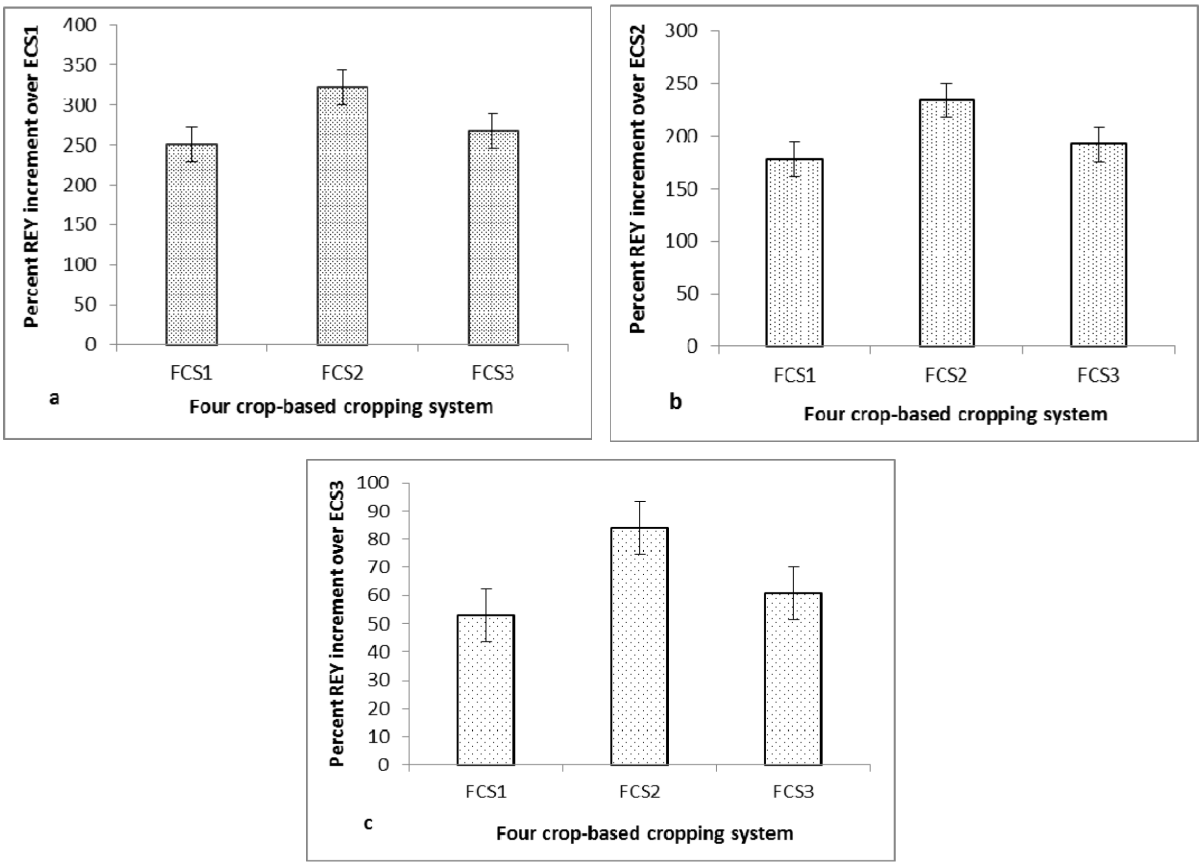

Figure 2. Percent rice equivalent yield (REY) increment of four crop-based cropping systems over existing cropping system ECS_1 (a), ECS_2 (b) and ECS_3 (mean data of two years)

Note. FCS = Four crop-based cropping system: FCS_1 = Mustard-Mungbean-T. Aus rice-T. Aman rice; FCS_2 = Lentil-Mungbean-T. Aus rice-T. Aman rice; FCS_3 = Fieldpea-Mungbean-T. Aus rice-T. Aman rice. ECS = Existing traditional cropping system: ECS_1 = Mustard-Jute-Fallow; ECS_2 = Lentil-Jute-Fallow; ECS_3 = T. Boro rice-T. Aman rice-Fallow.

Total field duration of crops of the cropping systems showed variation across the cropping systems (Figure 3a). The highest duration (344 days) was taken from FCS_3 system followed by FCS_2 and FCS_1 system treatment. Lowest duration (196 days) was consumed in ECS_1 system followed by ECS_3 and ECS_2 system treatment (Figure 3a). The seedling age of T. Aus rice, T. Aman rice and T. Boro rice was not considered. It has been observed that the existing traditional cropping systems (two crop-based) were turned around time 169 days from ECS_1, 140 days from ECS_2 and 154 days from ECS_3 (Figure 3b).

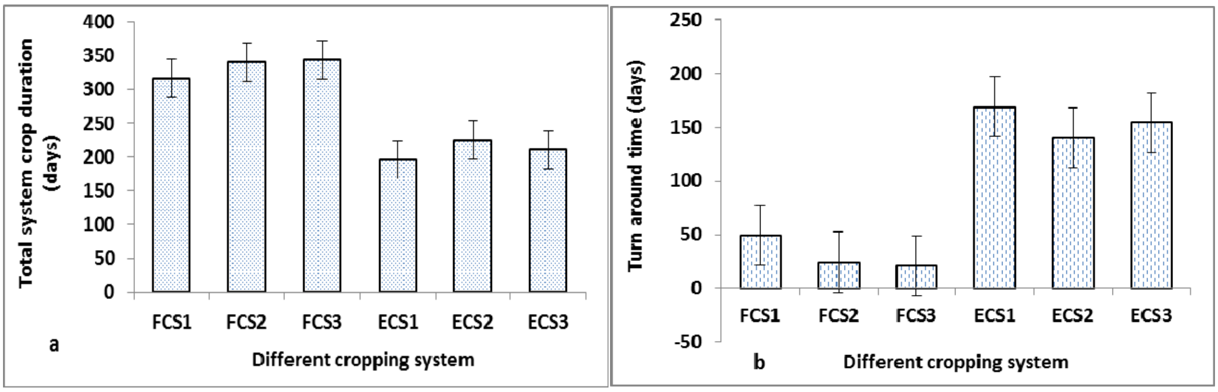

Figure 3. Assessment of different cropping systems on total system crop duration (a) and turnaround time (b) (mean data of two years)

Note. FCS = Four crop-based cropping system: FCS_1 = Mustard-Mungbean-T. Aus rice-T. Aman rice; FCS_2 = Lentil-Mungbean-T. Aus rice-T. Aman rice; FCS_3 = Fieldpea-Mungbean-T. Aus rice-T. Aman rice. ECS = Existing traditional cropping system: ECS_1 = Mustard-Jute-Fallow; ECS_2 = Lentil-Jute-Fallow; ECS_3 = T. Boro rice-T. Aman rice-Fallow.

Land use efficiency (LUE) value exhibited variation among the different cropping systems (Figure 4a). The four crop-based cropping systems showed highest land use efficiency (94.2%) in FCS_3 followed by FCS_2 and FCS_1 than the existing traditional cropping system ECS_1, ECS_3 and ECS_2. The lowest LUE (53.7%) was noted from ECS_1 system (Figure 4a). Production efficiency (PE) exhibited significant dissimilarity among the cropping systems (Figure 4b). The highest production efficiency (48.0 kg·day^{-1}·ha^{-1}) was recorded from FCS_2 system and the lowest (20.0 kg·day^{-1}·ha^{-1}) was from ECS_1 followed by ECS_2 system treatment (Figure 4b).

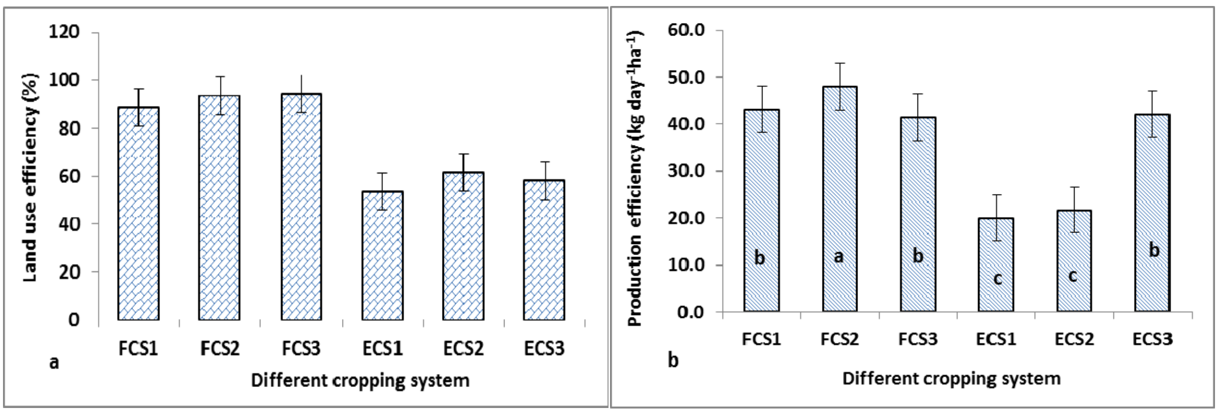

Figure 4. Performance of different cropping systems on the basis of land use efficiency (a) and production efficiency (b) (mean data of two years)

Note. FCS = Four crop-based cropping system: FCS_1 = Mustard-Mungbean-T. Aus rice-T. Aman rice; FCS_2 = Lentil-Mungbean-T. Aus rice-T. Aman rice; FCS_3 = Fieldpea-Mungbean-T. Aus rice-T. Aman rice. ECS = Existing traditional cropping system: ECS_1 = Mustard-Jute-Fallow; ECS_2 = Lentil-Jute-Fallow; ECS_3 = T. Boro rice-T. Aman rice-Fallow.

Values followed by the same letter are not significantly different according to the least significant difference (LSD) test at $p \le 0.05$.

3.3 Total Nutrients Uptake by Cropping Systems

Total uptakes of all nutrients were influenced significantly by different cropping systems (Figures 5a and 5b). The total N uptake was highest (316 kg ha^{-1}) from FCS_1 (Mustard-Mungbean-T. Aus rice-T. Aman rice) which was comparable with FCS_2, FCS_3 and ECS_2 treatments and significantly higher than the other treatments. The lowest N uptake was found from ECS_3 treatment (Figure 5a). Significantly the highest system P uptake (56.8 kg ha^{-1}) was recorded from ECS_2 (Lentil-Jute) treatment and lowest was from ECS_3 treatment. The maximum total K uptake (273 kg ha^{-1}) was obtained from FCS_1 (Mustard-Mungbean-T. Aus rice-T. Aman rice) that was similar to the treatment ECS_2 and FCS_2 and significantly different over the other treatments (Figure 5a). Cropping systems had an significant effect on total system S uptake where the highest total S uptake (36.7 kg ha^{-1}) was observed from FCS_1 (Mustard-Mungbean-T. Aus rice-T. Aman rice) treatment (Figure 5a). Total Zn and B uptakes were comparable for the treatments of FCS_2, FCS_1 and FCS_3 and all were significantly higher than the other traditional system treatments (Figure 5b).

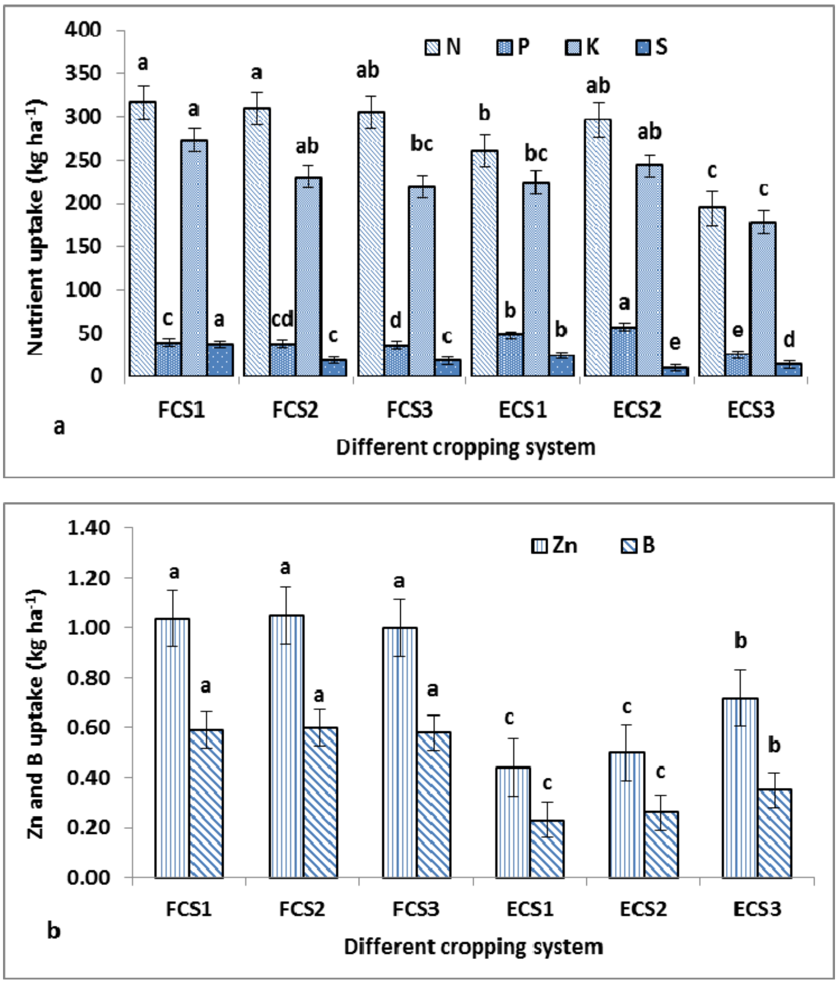

Figure 5. Effect of different cropping systems on total nutrient (N, P, K, S) uptake (a) and total Zn and B uptake by crops (mean data of two years)

Note. FCS = Four crop-based cropping system: FCS_1 = Mustard-Mungbean-T. Aus rice-T. Aman rice; FCS_2 = Lentil-Mungbean-T. Aus rice-T. Aman rice; FCS_3 = Fieldpea-Mungbean-T. Aus rice-T. Aman rice. ECS = Existing traditional cropping system: ECS_1 = Mustard-Jute-Fallow; ECS_2 = Lentil-Jute-Fallow; ECS_3 = T. Boro rice-T. Aman rice-Fallow.

Values followed by the same letter are not significantly different according to the least significant difference (LSD) test at $p \leq 0.05$.

3.4 Apparent Nutrient Balance of Cropping Systems

Different cropping systems affected the apparent balance of N, P, K, S, Zn and B (Figures 6a and 6b). Apparent N balance in different cropping systems indicated that the N balance exhibited negative value in most of the system except ECS_3. The highest N removal (-156 kg ha^{-1}) was observed from ECS_2 (Lentil-Jute) followed by FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice) cropping system and lowest N removal was from FCS_1

treatment (Figure 6a). The P nutrient was accumulated higher (21.4 kg ha^{-1}) in FCS_1 than the other FCS_3, FCS_2 and ECS_3 systems, but P was depleted from ECS_2 and ECS_1 where the higher depletion of P nutrient (-31.8 kg ha^{-1}) from ECS_2 system (Figure 6a). The highest amount (-133 kg ha^{-1}) of K depleted from ECS_2 system and lowest depletion of K was from ECS_3 system (Figure 6a). The highest accumulation of S (17.8 kg ha^{-1}) was recorded from FCS_3 followed by FCS_2 and lowest was from FCS_1 (Figure 6a). The highest Zn (6.50 kg ha^{-1}) and B (2.42 kg ha^{-1}) accumulation were found in FCS_3 system but depletion of B nutrient was occurred only from ECS_3 system (Figure 6b).

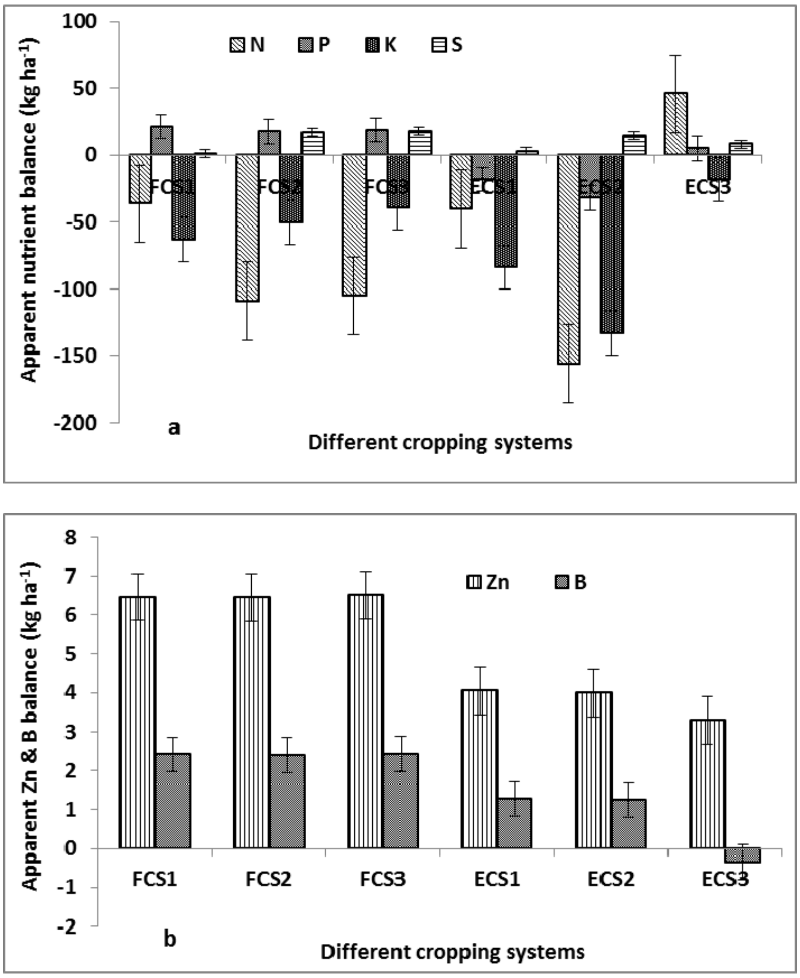

Figure 6. Apparent nutrient balance of N, P, K, S (a) and apparent nutrient balance of Zn, B (b) under different cropping systems

Note. FCS = Four crop-based cropping system: FCS_1 = Mustard-Mungbean-T. Aus rice-T. Aman rice; FCS_2 = Lentil-Mungbean-T. Aus rice-T. Aman rice; FCS_3 = Fieldpea-Mungbean-T. Aus rice-T. Aman rice. ECS = Existing traditional cropping system: ECS_1 = Mustard-Jute-Fallow; ECS_2 = Lentil-Jute-Fallow; ECS_3 = T. Boro rice-T. Aman rice-Fallow.

3.5 Effect of Cropping System on Postharvest Soil Properties

After completion of two cycles, the cropping systems (FCS_1, FCS_2, FCS_3, ECS_1, ECS_2 and ECS_3) affected the soil fertility (Table 6). The soil pH of cropping systems was observed almost slightly decreased with the initial reference status (Table 6). The organic carbon and total N of soil was found slightly increased in all the cropping systems over the initial status. The highest soil organic carbon content was found (8.78 g kg^{-1}) in FCS_3 (Fieldpea-Mungbean-T. Aus rice-T. Aman rice) which was significantly different over the other cropping systems. The lowest soil organic carbon content was recorded from ECS_1 (Mustard-Jute) cropping system, but it was found higher than the initial status. The highest total N content (0.74 g kg^{-1}) was obtained from FCS_3

(Fieldpea-Mungbean-T. Aus rice-T. Aman rice) followed by FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice) cropping system and the lowest were recorded from ECS_1 and ECS_3 system, but it was observed higher over the initial status (Table 6). Decreasing tendency of Ca and Mg content in postharvest soil was found in all cropping systems with the initial status. The K content in soil among the cropping systems was found slightly decreased or unchanged from the initial status. The P and S content in soil among all cropping systems was observed slightly increased from the initial soil status. The Zn and B content in soil among the cropping systems were found almost similar or slightly increased from the initial soil status (Table 6). The above variation might be due to various amounts of crops residues were mixed in the respective system's soil.

Table 6. Different cropping systems affected postharvest soil pH and status of different nutrients after completion of two cycles with reference to opening soil

Cropping system	pH	OC	Total N	Ca	Mg	K	P	S	Zn	B
		----- g kg^{-1} -----		------ meq. 100 g^{-1} ------			------------- mg kg^{-1} -------------			
Four crops system opening soil	7.4	8.15	0.63	12.8	4.5	0.14	15	16.2	0.88	0.17
Existing cropping system opening soil	7.5	8.32	0.64	13.2	5.1	0.15	16	15.9	0.90	0.16
FCS_1	7.2b	8.55c	0.69b	12.1bc	4.34d	0.13ab	15.4c	16.5a	1.0c	0.18a
FCS_2	7.3ab	8.71b	0.73a	12.2b	4.29e	0.12b	15.6c	16.6a	1.2a	0.18a
FCS_3	7.4a	8.78a	0.74a	12.1bc	4.42c	0.13ab	15.5c	16.5a	1.0c	0.17ab
ECS_1	7.3ab	8.43e	0.67c	12.0c	4.67a	0.14a	16.1b	16.1c	0.99c	0.16bc
ECS_2	7.4a	8.52d	0.69b	12.5a	4.64b	0.13ab	16.3ab	16.3b	1.1b	0.17ab
ECS_3	7.2b	8.44e	0.67c	12.2b	4.66a	0.14a	16.4a	16.5a	1.1b	0.15c
CV (%)	0.87	0.07	0.91	0.62	0.22	6.20	0.76	0.60	1.1	4.47

Note. FCS = Four crop-based cropping system: FCS_1 = Mustard-Mungbean-T. Aus rice-T. Aman rice; FCS_2 = Lentil-Mungbean-T. Aus rice-T. Aman rice; FCS_3 = Fieldpea-Mungbean-T. Aus rice-T. Aman rice. ECS = Existing traditional cropping system: ECS_1 = Mustard-Jute-Fallow, ECS_2 = Lentil-Jute-Fallow, ECS_3 = T. Boro rice-T. Aman rice-Fallow.

Values within the same column with a common letter do not differ significantly ($P \leq 0.05$).

3.6 Cost and Return Analysis

The cost and return analysis on different cropping systems are presented in Table 7. Result revealed that the highest gross return (BDT 327360 ha^{-1} yr^{-1}) and gross margin (BDT 195273 ha^{-1} yr^{-1}) was recorded from the treatment FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice) followed by FCS_3 (Fieldpea-Mungbean-T. Aus rice-T. Aman rice). The highest benefit cost ratio (2.48) was also recorded from the same FCS_2 system treatment. The lowest benefit cost ratio was recorded from the existing traditional Mustard-Jute cropping system (ECS_1) (Table 7).

Table 7. Effect of different cropping systems on cost and return analysis (mean data of two years)

Cropping system	TVC (BDT ha^{-1} yr^{-1})	Gross return (BDT ha^{-1} yr^{-1})	Gross margin (BDT ha^{-1} yr^{-1})	BCR
FCS_1	140264	272160	131896	1.94
FCS_2	132087	327360	195273	2.48
FCS_3	127916	285860	157944	2.24
ECS_1	75187	77560	2373	1.03
ECS_2	64438	97880	33442	1.52
ECS_3	80016	177800	97784	2.22

Note. FCS = Four crop-based cropping system: FCS_1 = Mustard-Mungbean-T. Aus rice-T. Aman rice; FCS_2 = Lentil-Mungbean-T. Aus rice-T. Aman rice; FCS_3 = Fieldpea-Mungbean-T. Aus rice-T. Aman rice. ECS = Existing traditional cropping system: ECS_1 = Mustard-Jute-Fallow; ECS_2 = Lentil-Jute-Fallow; ECS_3 = T. Boro rice-T. Aman rice-Fallow.

Inputs price: Ploughing (single pass) = BDT 1875 ha^{-1}, Wage rate = BDT 300 day^{-1}, Urea = BDT 16 kg^{-1}, Triple super phosphate = BDT 22 kg^{-1}, Muriate of potash = BDT 17 kg^{-1} , Gypsum = BDT 6 kg^{-1}, Borax = BDT 145 kg^{-1}, Zinc sulphate = BDT 140 kg^{-1}, Lentil seed = BDT 100 kg^{-1}, Mustard seed = BDT 50 kg^{-1}, Mungbean seed = BDT 100 kg^{-1}, Field pea seed = BDT 80 kg^{-1}, Boro rice seed = BDT 40 kg^{-1}, Aman rice seed = BDT 40 kg^{-1}, Aus rice seed = BDT 40 kg^{-1}, Jute seed = BDT 200 kg^{-1}, Irrigation = BDT 100 $hour^{-1}$

Output price: Boro rice = BDT 20 kg^{-1}, T. Aman rice = BDT 20 kg^{-1}, T. Aus rice = BDT 20 kg^{-1}, Jute fiber = BDT 20 kg^{-1}, Mustard = BDT 30 kg^{-1}, Lentil = BDT 70 kg^{-1}, Mungbean = BDT 65 kg^{-1}, Fieldpea = BDT 40 kg^{-1}

Gross returns were calculated on the basis of farm gate price of Madaripur, Bangladesh. BDT is Bangladesh currency, Bangladeshi Taka; 1 USD = 82 BDT. TVC = Total variable cost, BCR = Benefit cost ratio.

4. Discussion

4.1 Crop and System Rice Equivalent Yield

Shifting the traditional two crop-based cropping systems to four crop-based cropping systems can play a vital role for achieving sustainable food security and good nutrition. Among four crop-based cropping systems, the yield of mungbean and rice (T. Aus and T. aman) was obtained comparatively higher in Lentil-Mungbean-T. Aus rice-T. Aman rice cropping system. The reason of higher yield might be due to incorporation of legume residues in soil which inhances the soil health. Similar report outlined by Kumar and Yadav (2018) that legumes are contributed to increase the diversity of soil flora and fauna giving a greater stability to the total life of the soil. Legumes are assisted to restoration of soil natural matter and limit pest and disease issues when used in cropping system with non-legume crops (Yuvaraj et al., 2020). The first crops of three traditional cropping systems were mustard, lentil and T. Boro rice, the second crop was jute and T. Aman rice. In the study, the yield of jute fiber was comparatively higher in Lentil-Jute cropping system than that of Mustard-Jute cropping system. Mustard crop might be utilized the full amount of supplied nutrients from soil and very negligible amount was left for the following crops. Ahmed et al. (2019) corroborated the similar view in mustard (BARI Sarisa-14) production. On the other hand, legume crop might be left residue in soil which enhances to get higher yield of succeeding crop. Kumar and Yadav (2018) corroborated that legume (lentil) has inherent capacity to fix atmospheric nitrogen and addition of huge amount of organic matter through roots and leaves fall. Legumes also contribute to an increased diversity of soil microbe's influence to increase the soil health and sustained soil fertility (Ghosh et al., 2014). System rice equivalent yields (REY) of four crop-based cropping systems were higher than the existing traditional cropping systems (two crop-based). The percent REY increment of improved cropping system (Lentil-Mungbean-T. Aus rice-T. Aman rice) was 322%, 234% and 84.1% higher compared to the existing cropping systems due to get the higher market price of lentil and adds new crop intensification and diversification. Comparable result reported by Rahman et al. (2020). Similar judgment outlined by Ahmed et al. (2019); Hossain et al. (2018), Chowdhury et al. (2017). The system REY was two to three folds higher in four crop-based cropping systems than the existing cropping systems. Similar results corroborated by Singh et al. (2013), Samant (2015), and Mondal et al. (2015). Saha et al. (2019) reported crop intensification in cropping system increased 211 to 360% more REY by two to four crop-based cropping system in the salt-affected coastal zones of Bangladesh. However, the quantity acceleration of REY fluctuates due to involvement of the number of crops in the cropping system (two or three or four crop-based system), type of crops and several ecosystems. Several researchers have been reported that cropping system magnification from double (rice-rice or rice-wheat) to triple cropping system (Wheat-Mungbean-T. Aman) increased the system REY by 10-75% in the High Ganges

River Floodplain and Madhupur tract of Bangladesh (Alam et al., 2021) and 82% higher system REY when compared to double to four crop-based systems (Hossain et al., 2014).

4.2 System Duration, Land and Production Efficiency

Cropping system duration is an important factor for land use and production efficiency. However, different cropping systems showed duration variation among them. In the study, highest duration (344 days) was taken by FCS_3 (Fieldpea-Mungbean-T. Aus rice-T. Aman rice) and lowest was by FCS_1 (Mustard-Jute) system treatment. The existing traditional cropping systems (two crop-based) were turned around time 169 days from ECS_1, 140 days from ECS_2 (Lentil-Jute) and 154 days from ECS_3 (T. Boro rice-T. Aman rice), however short duration high yielding variety of mungbean, T. Aus and T. Aman rice could easily be fitted in the traditional cropping systems in a year instead of jute and Boro rice. Similar statement corroborated by Mondal et al. (2015), Rahman et al. (2018), and Ahmed et al. (2019). Jute cultivation in the experimental area was discouraged due to unavailability of jute rotting water and got lower market price. Similar judgment was made by Ahmed et al. (2019). In this context, mungbean could easily be introduced after harvesting of mustard and lentil to replace jute. Rice is the staple food in Bangladesh, but T. Boro rice has taken long life cycle (140-160 days) and consumed higher water and nutrient. In this situation, mustard/lentil and mungbean could easily be introduced after harvesting of T. Aman rice to replace the T. Boro rice. Chowhan et al. (2021) reported similar in Boro rice-Aman rice cropping system. Land use efficiency (LUE) has been varied across the cropping systems. The percent LUE increment was calculated highest in Fieldpea-Mungbean-T. Aus rice-T. Aman rice system as 75% over ECS_1, 52.9% over ECS_2 and 62.9% over ECS_3 system, respectively. The results are in agreement with the findings of Islam et al. (2018) and Kamrozzaman et al. (2015). In our study, the highest production efficiency (PE) was documented in FCS_2 (Lenti-Mungbean-T. Aus rice-T. Aman rice) system due to the contribution of lentil market price. Higher production efficiency might be related to the introduction of four crops with modern varieties in the existing system and better management practices. Comparable findings were outlined by Rahman et al. (2020), Ahmed et al. (2019), Chowdhury et al. (2017), and Nazrul et al. (2013, 2017) in case of improved cropping systems.

4.3 Nutrient Uptake by Cropping Systems

Generally the amount of nutrients taken up by the crops of cropping system exceeded the amount added through fertilizers are varied. The highest total N uptake value was obtained from FCS_1 (Mustard-Mungbean-T. Aus rice-T. Aman rice) cropping system due to higher uptake of N by T. Aus, T. Aman rice, and mungbean. Percent total N uptake increment of FCS_1 system over existing cropping systems ECS_1 (Mustard-Jute), ECS_2 (Lentil-Jute) and ECS_3 (T. Boro rice-T. Aman rice) were 21.5%, 6.76% and 62.9%, respectively. Hossain et al. (2018) corroborated the similar that N uptake was higher than existing system. Total N uptake increment of FCS_1 was higher might be due to get highest yield of the test crop in the system. The FCS_1, FCS_2 and FCS_3 systems seemed to be comparable N uptake, but all were showed better N uptake compared to the existing cropping system when soil fertility was considered (Hossain et al., 2018). Maximum total system P uptake was occurred in the existing Lentil-Jute cropping system might be due to the higher dry plant yield of jute than the other crop and the P content value was also higher in jute dry plant. Similar observation corroborated by Singh et al. (2014); Singh et al. (2015) in Jute-Rice-Gardenpea sequence. Comparable result of K uptake was found in the study for FCS_1, FCS_2 and ECS_2 cropping system. Higher K uptake value was in FCS_1 (Mustard-Mungbean-T. Aus rice-T. Aman rice), FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice) and ECS_2 (Lentil-Jute) cropping system might be involved the individual crop yields and K content value. Comparable statement made by Quddus et al. (2017); Khan et al. (2006) in Lentil-Mungbean-T. Aman rice sequence. The K uptake result of the study was supported to the study of Shrestha and Ladha (2001) who outlined in K uptake by different pattern sweet pepper-fallow-rice (203 kg ha^{-1}); sweet pepper-indigo-rice (318 kg ha^{-1}); sweet pepper-indigo + mungbean-rice (303 kg ha^{-1}); sweet pepper-corn-rice (467 kg ha^{-1}). The S uptake was significantly varied among the different cropping systems where higher S uptake was found in FCS_1 system than the others. This higher S uptake might be related to the increase S accumulation by mustard plant resulted highest S content and uptake. The S uptake of plant depends on the synergistic relationship with other nutrients which ultimately enhance the yields of oilseed crops (Mehmood et al., 2021). Result of Zn and B uptake in the study was all most similar trend in FCS_1, FCS_2 and FCS_3 cropping system. Maximum uptake value of Zn and B was in FCS_2 cropping system which associated to the individual higher crop yields and greater Zn and B concentration in plant due to added the Zn and B fertilizer in soil. Zinc and B uptake results are confirmed by Hossain et al. (2008) in Maize-Mungbean-Rice squence and Debnath et al. (2011).

4.4 Apparent Nutrient Balance in Cropping System

Nutrient balance of the study was affected positively by different cropping systems. Apparent nutrient balance calculation was made on consideration of the annual nutrients input this came from fertilizer and annual nutrient uptake by the crops of cropping systems. From the result of apparent nutrient balance, the total uptake of N and K exceeded the applied input (fertilizer) for all cropping systems but the total uptake of P, S, Zn and B was not exceeded the applied input except P uptake for ECS_1 (Mustard-Jute) and ECS_2 (Lentil-Jute) system. Study publicized that the highest N depletion was happened from ECS_2 (Lentil-Jute) cropping system. This highest negative N balance might be due to higher N uptake by jute. Timsina et al. (2010) reported that apparent nutrient balance of N showed highly negative (-120 to -134 kg ha^{-1} yr^{-1}) in rice-maize systems. On the other hand, lentil was utilized lower amount of N fertilizer. Literature indicated a starter dose of N is needed for establishment of legume crop afterward they fixed atmospheric N_2 for their existence through symbiotic process (Faligowska et al., 2022). The second greater removal of N was from FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice) followed by FCS_3 (Fieldpea-Mungbean-T. Aus rice-T. Aman rice) system treatment. Hossain et al. (2018) reported the similar view in Lentil-Mungbean-T. Aus-T. Aman rice cropping system in high barind tract soils of Bangladesh. The lower removal of N was from FCS_1 (Mustard-Mungbean-T. Aus rice-T. Aman rice) due to higher amount of total N fertilizer was applied in soil than the other system. Apparent P balance was positive in all cropping system except P for ECS_1 and ECS_2 treatment. The apparent P balance was found positive in rice-maize system (Ali et al., 2009). The negative balance of P in ECS_1 (Mustard-Jute) and ECS_2 (Lentil-Jute) indicated that the applied amount of P fertilizer was lower than the other cropping systems but the crops of the system (ECS_1 and ECS_2) were highest P uptake especially by jute. As a result, the apparent P balance showed negative. Positive balance of P indicated adequate in soil but plant tissue (lentil, mustard and jute) showed inadequate even under the recommended dose of fertilizer (Yoshida, 1981; Reuter et al., 1997). Constraints for achieving adequate P concentration in tissue (data not showed) and uptake could include unavailability of the applied P (due to chemical fixation, or inadequate moisture in the fertilizer zone) or inadequate rates; understanding the cause will require further investigation. The P deficiency in lentil, mustard or jute may be attributed to increase P sorption but reduced the P availability during the lentil, mustard or jute season. Comparable judgment made by Saleque et al. (2006) P deficiency in wheat or maize might be attributed to increase P sorption and reduced P availability and uptake. The recommended fertilization in all systems appeared to contribute slight P build-up in soil, but the low-P concentrations in grain of lentil, mustard and mungbean (data not presented) suggested to an increase dose of P fertilizer. Malhotra et al. (2018) reported that P nutrition is an important factor for increasing the leaf magnesium (Mg) concentrations in crop. In the study, the apparent K balance observed negative in all the cropping systems where the maximum removal was in ECS_2 (Lentil-Jute) system and second in ECS_1 (Mustard-Jute) system. The negative K balance depends on the system crops uptake and leaching loss of the nutrient. The K negative balance builds up higher mainly due to the crop uptake in the system. Biswas et al. (2006) found that the apparent average annual K balance was negative in the system of jute-rice-rice and rice-potato-sesame. T. Boro rice-T. Aman rice cropping system showed the K lesser mining from soil due to the higher amount of K fertilizer was applied. The results confirmed in many systems similar to several long term studies in rice-rice and rice-wheat systems of Asia (Yadvinder et al., 2005; Ladha et al., 2003). In the study, the apparent balance of S was maintained a positive balance in all the cropping systems where the highest S accumulation was found in FCS_3 (Fieldpea-Mungbean-T. Aus rice-T. Aman rice) followed by FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice) which seemed to contribute higher S build up in soil but low S detection in lentil, mungbean and rice (data not presented). However, the crops of these systems suggested an increased dosage of S fertilizer (Yoshida, 1981; Reuter et al., 1997). The apparent zinc balance in the study was found positive in all the cropping systems as focused the Zn fertilizer was applied in soil. The apparent balance for B was negative only in ECS_3 (T. Boro rice-T. Aman rice) cropping system and almost all cropping system showed positive due to B fertilizer was used. It has been reported that the B positive balance in maize-mungbean-rice system when it was applied (Hossain et al., 2008). Quddus et al. (2017) reported that the deficiency detection of B in the seed of lentil and mungbean and sufficiency detected in rice grain (data not showed). However, the B fertilization is needed in legume related cropping system.

4.5 Soil Fertility Changes

After two years cycle, there was a very little change of soil pH in different cropping systems compared to initial soil. The static or slightly decrease in soil pH happened probably due to the production of organic acids in decomposition of legumes biomass (mungbean and lentil) and other crop residues. Decreases in soil pH were reported by several researchers in their different studies of cropping systems (Chadha et al., 2009; Hossain et al., 2016a, 2018). Soil organic carbon (SOC) was increased slightly due to legumes and other crop residues amalgamation in soil (Mondal et al., 2015; Yusuf et al., 2009). The inclusion of crop residues including legumes in soil of the cropping systems have been increased the SOC status ((Hauggaard-Nielsen et al., 2007; Hossain et al., 2018). Similarly N content was slightly increased in postharvest soils of all cropping systems compared to the initial value. The mungbean biomass utilized as source of N, legume nodulation might be accelerated nitrogen fixation by free-living organisms (Dhakal et al., 2016). Furthermore, legumes have positive effects on soil processes such as benefiting agro-ecosystems, agricultural productivity, soil conservation, soil biology, SOC and N stocks, soil chemical and physical properties, BNF, nitrous oxide (N_2O) emission, and nitrate (NO_3) leaching by means of lowering the need for chemical fertilizers (Stagnari et al., 2017; Kumar & Yadav, 2018). Legumes are currently utilized as soil nourishment agents (Yuvaraj et al., 2020). Compared with the initial value, the available P content of soil increased due to incorporation of legume and other crops residues and inorganic P supplied. Similar observation outlined by Alamgir et al. (2012) that legume residues mobilized P addition in soil. Jensen et al. (2012) corroborated the same view. In the study, calcium and Mg content was exhibited almost declining tendency in most of the cropping systems with the initial soil status. Exchangeable Ca and Mg decreasing in soil might be due to no use of Ca and Mg containing fertilizer. Exchangeable K was slightly declined in all the cropping systems in postharvest soil with compared to initial soil K value. This result indicates a higher uptake of K in all the cropping systems than the K amount added that led to the reduction of K in a long time. Result is supported by Panaullah et al. (2006). The S content in soil was observed static/slightly increased in different cropping systems from the initial soil. Available Zn and B content showed an increasing trend across the cropping systems reference to opening soil. But B content was declined in postharvest soil only in Rice-Rice cropping system might be due to no use of B fertilizer.

4.6 Profitability of Cropping System

Cropping systems have been progressively significant worldwide especially Asia in agricultural production. Improving crop productivity and crop intensification in the cropping system contributed to arresting the worsening economic conditions (Kaosa-ard & Rerkasem, 1999). Researcher's community has already been started working on crop intensification and improving the existing cropping system without environmental hazard to prevent food security and nutrition and improve the economics for sustainable livelihoods. However, the field study of different cropping systems exhibited higher gross margin and benefit cost ratio (BCR) in four crop-based cropping systems than the existing cropping system except Rice-Rice system for BCR. The results are in agreement with the findings of Ahmed et al. (2019), Hossain et al. (2018), and Chowdhury et al. (2017). The FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice) system having the highest percent increment of BCR was 140% over ECS_1 (Mustard-Jute), 63.2% over ECS_2 (Lentil-Jute) and 11.7% over ECS_3 (T. Boro rice-T. Aman rice) system. This higher BCR might be related to the higher rice equivalent yield and higher market price of legume crops. Similar findings documented by Nazrul et al. (2017), Nazrul et al. (2013), and Khan et al. (2005) in case of improved cropping systems. The experimental calculation had been focused based on gross margin and BCR, the FCS_2 (Lentil-Mungbean-T. Aus rice-T. Aman rice) followed by FCS_3 (Field pea-Mungbean-T. Aus rice-T. Aman rice) systems are economically profitable and viable.

5. Conclusion

Results and discussion of the study concluded that the highest percent rice equivalent yield increment over existing cropping systems was achieved from Lentil-Mungbean-T. Aus rice-T. Aman rice, second highest from Fieldpea-Mungbean-T. Aus rice-T. Aman rice and third highest from Mustard-Mungbean-T. Aus rice-T. Aman rice cropping system. The land use and production efficiency were obtained higher from four crop-based cropping systems. All four crop-based cropping systems were economically profitable and viable. Benefit cost ratio was comparatively higher in Lentil-Mungbean-T. Aus rice-T. Aman rice cropping system than that of others existing and improved cropping systems. Soil fertility like organic carbon and total N was comparatively higher in Fieldpea-Mungbean-T. Aus rice-T. Aman rice followed by Lentil-Mungbean-T. Aus rice-T. Aman rice cropping system. Hence, intensification and diversification of crops with short duration high yielding variety in a land annually lead to increase the system productivity, profitability and sustaining soil fertility and employment opportunity could be created for the rural poor as well as change the farmer's livelihoods. Results suggest that lentil-Mungbean-T. Aus rice-T. Aman rice followed by Fieldpea-Mungbean-T. Aus rice-T. Aman rice cropping system can practice in the experimental area. This finding may be potential for the area where there is no practice of improving four crop-based cropping systems.

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