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Profitability analysis of paddy production in different seasons in Bangladesh: Insights from the *Haor*

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Abstract
This study aimed to investigate the cost-benefit per hectare of rice production in the *haor* region in Bangladesh. For doing so, the multi-stage sampling technique was used to collect cross-sectional data during 2018 from four *haor* districts producing rice in Bangladesh. To achieve the purpose, a total of 368 randomly selected farming households from Habiganj, Sunamganj, Moulvibazar, and Sylhet districts were surveyed using a structured questionnaire. Data analysis was done utilizing descriptive statistics and cost and return analysis. The result revealed that labor costs constituted the largest proportion of gross operating expenses, followed by fertilizer, irrigation, tillage, insecticides and herbicides, and threshing cost. The cost-benefit analysis finding also shows that rice is a profitable enterprise in the *haor* areas as the lower production cost compared to return. Because of the amount of input used and the price of output, the profitability differs between different seasons, however. The model shows that cost of seed, human labor cost, cost of TSP, cost of MoP, and cost of irrigation were the key factors that influenced rice production. This study also identified some of the problems related to rice production in *haor* areas. Lower output price, higher input price, unavailability of short growth duration high yielding varieties, and embankment damages, etc., are key obstacles to rice production. Therefore, this study provides the government's concerned authority with appropriate suggestions and policy recommendations to solve the farmers' issues that could boost rice productivity in the *haor* areas and contribute to food security and self-sufficiency in rice cultivation.

Keywords
Rice, Productivity, Profitability, Haor, Bangladesh

Introduction

Bangladesh is a densely-populated, low-lying, mainly riverine country located in South Asia (Islam et al., 2020; Rahman et al., 2021). Bangladesh's economy relies mostly on agriculture, which is undergoing a steady transition from traditional to modern. (Rahaman et al., 2021; Sarker et al., 2019) . Within the context of this development process, Bangladesh's agricultural industry is of critical significance. (Hoq et al., 2021; Sarkar et al., 2022). Agriculture is the single largest producing sector of the economy since it comprises about 14.23 percent of the country's GDP and employs around 40.06 percent of the total labor force (BER, 2018; LFS, 2018). Where paddy production dominates by covering 11.97 million hectares of land, which is about 74.85 percent of the total cropped area and more than 65 percent of the irrigated area of the country, and stands third among the rice producing countries (BBS, 2018; MoA, 2019; Rahman et al., 2021). Rice is the main dietary staple for 164.6 million people and provides about 55% and 75% of total protein and calories in the daily human diet, respectively (BBS, 2018; Kabir et al., 2003).

Almost all over the country, rice is produceding three seasons (Rahaman et al., 2020; Mondal et al., 2019). Kharif-I (mid-March to mid-July), Kharif-II (mid-July to mid-October), and Rabi (mid-October to mid-March) are the three rice growing seasons (Hoq et al., 2021). Between the dry and wet seasons, Kharif-I (early monsoon) serves as a transitional time, whereas Rabi and Kharif-II are the wet and dry seasons, respectively (Chowdhury and Hassan, 2013; Alamgir et al., 2020). Growing seasons for rice were Aus, Aman, and Boro, which correspond to Kharif-I, Kharif-II, and Kharif-III, respectively (Talukder and Chile, 2014). Being a vital source of rice production, *haor* areas play a significant role in the economy of Bangladesh (Rahaman, et al. 2018). *Haor* areas covered about 0.71 million hectares of net cultivable land, of which more than 5.25 million tons of paddy each year has been produced (BHWDB, 2012). Territorially, many haors are situated in Bangladesh's North-eastern portion (Alam et al., 2010; Hoq et al., 2021; Rahaman et al., 2018). *Haor* is now being used to indicate a unique geographical site of Bangladesh that added a splendid diversity to the country's nature, which is flood-prone and other low lying areas that remain inundated with water from June to November. About 859,000 ha (around 43%) of the total area of the *haor* region is covered by the number of 373 *haors*. Out of these, In Sunamganj district surrounded by 95 *haors* of which about 70% area has now been turned into cultivated land (BHWDB, 2012).

In *haor* areas, a major portion of their cultivable land is low land. Bangladesh's most flood-prone regions are the low-lying haor regions, which experience floods due to erratic rainfall during the rainy. As a result during *Kharif* –1 (Aus) and *Kharif* –2 (Aman) lands became fallow due to inundate on floodwater. In the haor area *Boro* is the main crop and is frequently affected by flash flood (Hoq et al., 2021; Ali and Rahman, 2017). Among the different cropping patterns, *Boro*-fallow-fallow (39.64%), *Boro*-fallow-T. *Aman* (15.74%), fallow-fallow- T. Aman (15.29%), and fallow-*Aus*-T. *Aman* (12.62%), were the main and exclusive rice-based pattern in the *haor* region (Muttaleb et al., 2017).

In the *haor* region, rice is the main crop and even the only crop due to lengthy waterlogging conditions (Alam et al., 2010; Aziz and Kashem, 2016; Hoq et al., 2021; Ali and Rahman, 2017). In those areas, rice cultivation mainly depends on the natural water, although artificial irrigation is managed in some possible localities. The production of such areas is confined under the choice of nature. Sometimes the ripened rice is damaged by the uncertain floodwater in the shallow areas. Despite growing just Boro rice as a single crop and the recurrence of advanced flash floods, the area alone provides a living for twenty million haor residents and generates around 20% of the nation's total rice production (Rabby et al., 2011). According to Huda (2004), boro rice covers about 80% of these haor regions, whereas T. Aman rice occupies just around 10% of the total area. Additionally, the haor zones also cultivate hybrid rice (Das, 2004). Compared to the rest of the country's irrigated regions, the haor zones are far more natural hazardous. Increasing global warming has made the haors more aggressive in their refusal to provide a safe harvest. During the early reproductive stage of the crop, cold injury, flash flood damage, etc., are all common occurrences in the haor region's rice farming. Besides, floods, cyclones and storm surges, hailstorms, drought, tornados, riverbank erosion, and landslide are the main impediments to growing paddy in this area (Alam et al., 2010).

Several studies have been undertaken in the hoar regions to determine the socio-economic repercussions of the disaster, sanitation patterns, flood risk, cropping patterns, etc. (Antwi et al., 2015). An empirical finding reveal that flash floods adversely impact the majority of the haor population, whose rural families rely on agriculture and aquaculture for their livelihoods, and many of them are vulnerable to food insecurity (Shaw 2006; Rahman et al. 2015; FAO 2017). Both Rahman et al. (2018a) and Rahman et al. (2018b) analyzed the floodplain haor area's susceptibility to climatic pressures and policies on climate adaptation, respectively. Research by Rahman and Hickey (2019a) sought to discover sustainable rural livelihood frameworks as well as institutional solutions to climate change by Rahman and Hickey (2019b). Alam, et al. (2010) stated that the major hinders to the adoption of potent cropping patterns were embankment damages and scarcity of shorter growth duration high yielding varieties. While Ali et al. (2019) attempt to show the *Boro* rice cultivation and agro-economic performance in the *haor* area. He found that the productivity of *Boro* rice is low due to the imbalance use of fertilizers. Rahaman et al. (2018) evaluate the productivity, profitability, resource use efficiency, and farmers' perception of growing BRRI dhan29 and hybrid rice production in the *haor* area. The study revealed that per hectare variable cost of the hybrid was about 12% higher than BRRI dhan29, where the yield of BRRI dhan29 was about 12% lower than hybrid rice.

As a result, efforts have been made to investigate the economic analysis of paddy output throughout the various seasons in the haor area. This is because developing a rice pricing strategy for this region is extremely necessary. The cultivation of rice necessitates a variety of processes, including the preparation of the land, planting of seedlings, weeding, application of fertilizer and insecticides, irrigation, harvesting, carrying, threshing, and winnowing of the grain, and the drying of the finished product. Rice production thus requires a significant financial investment on the part of farmers. That's why we carried out this research: we wanted to have a better grasp on the economics of rice farming in the haor regions at various times of the year. This research can potentially educate farmers about the primary expenses associated with rice cultivation, assisting them in being more productive and thereby increasing their revenue. In light of this, the overall purpose of this research was to investigate the relationship between farmer income and expenditure and to compare the costs and benefits of producing rice in various seasons in Bangladesh. The specific objectives of the study were as follows: i) to evaluate the adoption situation of modern and local rice varieties; (ii) to determine the level of inputs used and estimate the cost and profitability of rice cultivation in different seasons; and (iii) to identify the factors that contribute to rice production.

Methodology

Study area

The research regions were deliberately chosen to be the Habiganj, Sunamganj, Maulavibazar, and Sylhet districts in consideration of the study's goals. A total of eight Upazila (Tahirpur, Bishwambarpur, Chunarughat, Baniachang, Maulvibazar Sadar, Srimangal, South Surma and Golapganj) were also selected purposively from four districts (Figure 1). The study sampled a total of sixteen villages, of which two from every Upazila for the farm-level survey.

In the north-eastern section of Bangladesh, the Sylhet agricultural area has the finest blend of haor, bawor, bills, hills, rivers, forests, and flatlands. It is located within the eastern Surma-kusiyara floodplain, the Sylhet basin, the northern and eastern piedmont plain, the northern and eastern hills, the former Meghna estuary floodplain, and the Akhaura terrace agro-ecological zone (BBS, 2018). This region has 0.77 million hectares of net cultivable land, with 0.21, 0.13, 0.18, and 0.28 million hectares of net cultivable land, respectively, in the districts of Sylhet, Moulvibazar, Habiganj, and Sunamganj (BBS, 2018 and Muttaleb et al., 2017). About 0.43 million hectares of the region are cultivated with only one crop, 0.28 million hectares with two crops, and 0.04 million hectares with three crops. At the moment, Bangladesh's cropping intensity is 200 percent, while in the Sylhet area, it is just 148 percent (Muttaleb et al., 2017).

Sample distribution

A total of 368 sample farmers were interviewed, of which 80, 128, and 160 were of *Aus*, *Aman*, and *Boro*, respectively. The sample farmers were chosen using a straightforward random sampling technique. Five Aus farmers, eight Aman farmers, and ten Boro farmers were randomly selected from each village on average to gather the essential data for the research

Data

The farmers were surveyed in April-June 2018 with a structured questionnaire. The questionnaire was designed to collect farmers' income, expenditure, and the net profit of rice production in a different seasons. Data was also collected on the farmer's socio-economic information, farm characteristics, and rice production. These included information on age, household members, household labor, farming experience, farm size, and the detail of growing rice varieties. The pre-test was conducted ahead of data collection to review the questionnaire before conducting the main survey.

Season considered

Bangladesh has three different seasons: Aus, Aman, and Boro (BBS, 2018; Hoq et al., 2021). This research included all three seasons since rice is grown year-round in haor regions. For Aman season, we evaluated both broadcast Aman, which grows in low-lying sections of haor known as deepwater rice, and transplanted Aman, which grows on medium-height land. In addition, two cultivation settings are considered for the Boro season: one is grown in deep haor, or low-lying ground and the other is planted in medium-high land.

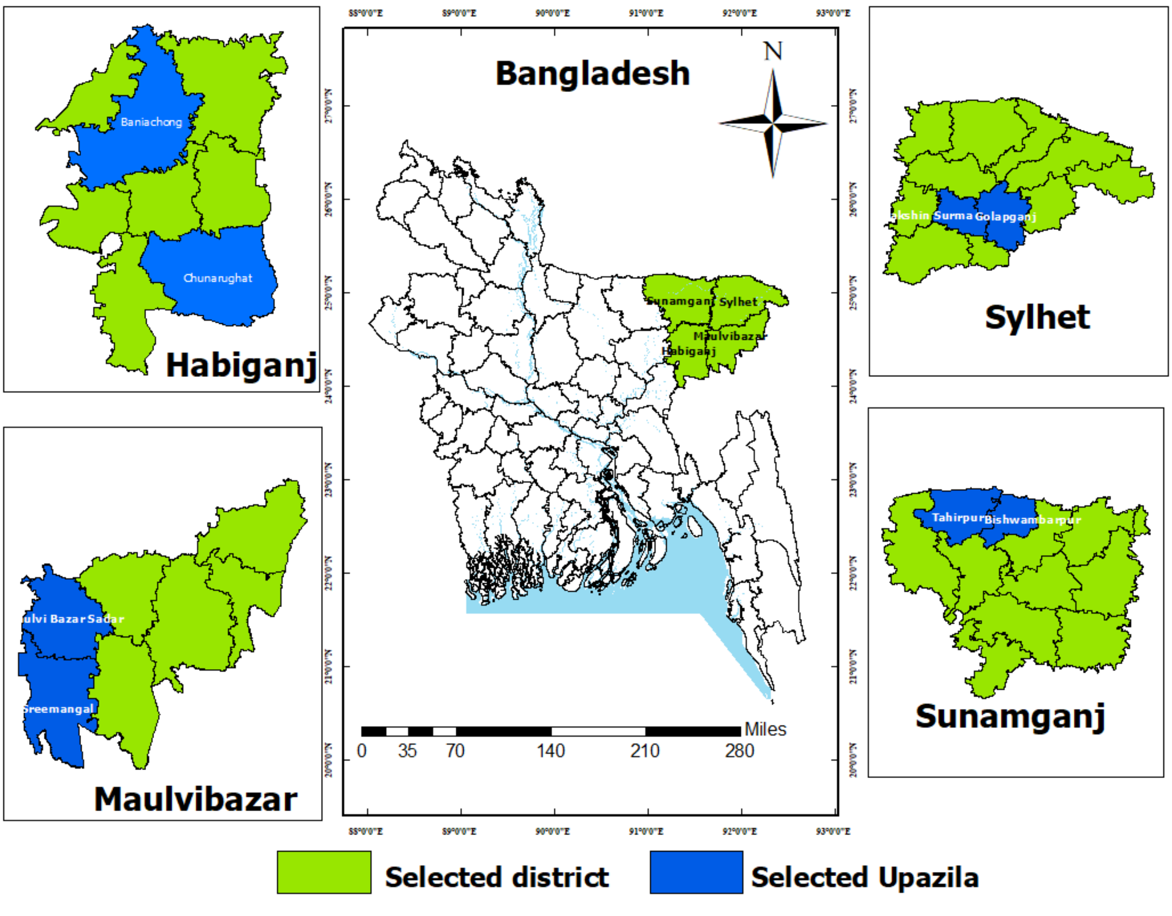

Figure 1. Study area

Analytical techniques

Description and mathematical analysis were employed to analyze the collected data. Descriptive statistics such as minimum, maximum, mean, and percentages analysis were employed to represent the socio-economic characteristics of the surveyed respondents.

Mathematical analysis

The profit function was employed in the case of the mathematical analysis. These include gross return, gross margin, net return, and benefit-cost ratio (BCR).

Gross return: Gross return was calculated by simply multiplying the total volume of output of rice with per unit price received by the farmers. It consisted of the sum of the volume of the main product and its by-product (Dillon and Hardaker, 1993).

Gross Return = Σ (Q x P)

Where Q = Output quantity; and P = Output price.

Gross margin: It is the difference between total return and variable cost.

Gross Margin = Gross return − Total variable cost

Net return: Net return was obtained by deducting all costs (variable and fixed) from gross return. ,

Net return, $\pi = \Sigma P_y Q_y - \Sigma (P_{xi} X_i) - TFC$.

Where, P_y = Per unit price-output; Q_y = Total quantity output; P_{xi} = Per unit price of i-th inputs;

X_i = Quantity of the i-th inputs; TFC = Total fixed cost (Tk); and i = 1, 2, 3,..............., n (number of inputs).

Benefit-cost ratio (BCR): The BCR is a relative measure, used to compare benefit per cost unit. The BCR estimated gross returns and gross costs as a ratio. The formula (undiscounted) for measuring BCR is shown below:

Benefit-cost ratio = Gross benefit ÷ Gross cost

Empirical Technique

The functional analysis was conducted to identify the key inputs which influenced the sampled rice farmers' production process. Cobb-Douglas production function model was used to evaluate the factor responsible. It is a conventional model where output volume is dependent on the degree of input utilization.

Model specifications are as follows:

$$Y = aX_i^{bi} + e^{ui} \quad (1)$$

Equation (1) is an equation not in linear form. A natural logarithm is used on both sides as follows, to make it linear:

$$\ln Y = lna + b_i X_i + u_i \quad (2)$$

Where Y= Total production (t/ha),

X_i= different variables susch as seed cost (Tk/ha); human labor cost (Tk/ha); land preparation cost (Tk/ha); Urea cost (Tk/ha); TSP cost (Tk/ha); MoP use (Tk/ha); Irrigation cost (Tk/ha); Manure cost (Tk/ha); Insecticide cost (Tk/ha); a = Constant or intercept term; b_i = Coefficients to be estimataed for the corresponding input variables; and u_i = Error term.

Results and Discussion

Socio-demographic profile of the sample farmers

Table 1 summarizes the socio-economic and demographic profiles of the respondent farmers. The socio-economic characteristics of rice farmers affect their farming operations either directly or indirectly (Bwala and John, 2018). The majority (58 percent) of farmers belonged to the active age group (between 31 and 50). As for schooling, over 90 percent of the heads of households in the surveyed region were educated; among them, 48 percent of the respondent's education level was secondary. Approximately all the households in the survey were male-headed with an average family size of 4.9, 49 percent of which were male. The sample farmers' average farm size was 1.95 acres, and the majority of farmers were small-scale farmers, around 71 percent. The sample households had a relatively long experience in rice farming, and the farmers had an average of 25 years of rice production experience; and agriculture was the primary source of livelihood in the *haor* region around 81 percent of farmhouses. The *haor* farmers mostly adopted high-yielding modern rice varieties, of which 97.49, 79.69, and 96.63 percent of HYV were adopted in the *Aus*, *Aman*, and *Boro* seasons, respectively.

Table 1. Socio-economic features of sample respondents of the study area

Characteristics	Unit
Age (%):	
20-30 years	23
31-50 years	58
51-above years	19
Education (%):	
Illiterate (0)	10
Primary (I-V)	30
Secondary	48
Higher secondary	11
Graduate and Above	1
Family size (no./household):	4.9
Male	2.4
Female	2.5
Average Farm size (acre)	1.95
Farm classification (%):	
Small	71
Medium	25
Large	4
Farming experiences (%):	
0-10 years	15

11-20 years	27
21-40 years	45
Above 41 years	13
Occupation (%):	
Agriculture	81
Petty business	11
Fishing	4
Service	1
Others	3
Modern variety adoption (%):	
Aus season	97.49
Aman season	79.69
Boro season	96.63

Source: Field survey, 2018

Status of rice cultivation

Sylhet region has diversified cropping patterns, of which rice-based were exclusive. Among the cropping patterns, *Boro*-fallow-fallow, *Boro*-fallow-T. *Aman*, and fallow-*Aus*-T. *Aman* was the most popular. In the fiscal year 2017-18, about 0.77 million hectares of land was under rice cultivation and produced 2.05 million ton of rice in the Sylhet region (BBS, 2018). Figure 2 shows the adoption percentage of a variety of types cultivated by farmers in the study area. Results show that farmers mostly adopted modern improved varieties in the surveyed area, among which BRRI varieties adopted more in three seasons. Farmers mostly adopted modern varieties in the *Aus* season. Among the adopted varieties BRRI dhan48, BRRI dhan28, BR26, and BR3 were popular with the farmers. On the other hand, BRRI dhan49, BR11, BR22, BRRI dhan32, BRRI dhan46, BRRI dhan51, and BRRI dhan53 varieties were popular in the *Aman* season. While for B. *Aman,* farmers generally cultivate local varieties, namely *Godalaki*, *Dudhlaki*, etc. Furthermore, in the *Boro* season, farmers also adopted modern varieties. BRRI dhan28, BRRI dhan29, BRRI dhan58, and hybrid varieties were the most dominant varieties in this region.

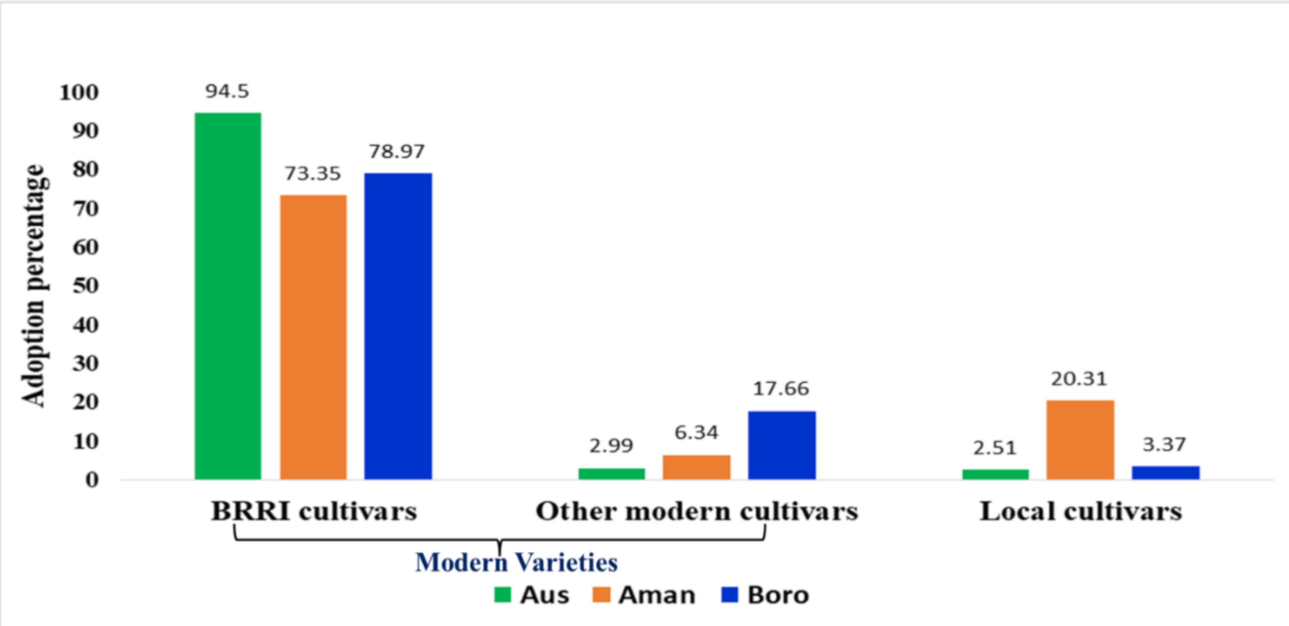

Figure 1. Types of varieties adopted by farmers in the study area

Paddy production practice

Table 2 shows the period rice was sown, transplanted, and harvested in various seasons. In the management practices, farmers in the Sylhet region sow seeds on May 6-13, July 8-15, May14-31, December 7-15 and November 4-15 for *Aus*, Transplanted *Aman*, Broadcast *Aman* (deepwater rice), *Boro* (medium high land), and *Boro* (cultivated in the main *haor*), respectively. Therefore, on May 26-30, August 15-30, January 24- February 5 and December 15-31, they transplanted seedlings for *Aus*, T. *Aman*, *Boro* (medium high land), and *Boro* (cultivated in the main *haor*), respectively. Farmers of this region use almost all types of fertilizer recommended for their cultivation. The application of phosphate fertilizer was higher, and MoP was much lower than the recommendation in all seasons as well. Farmers usually apply nitrogen fertilizer 2-3 times in the fields and irrigate the main field about three-four times a month. For weeding, farmers hired labor at least one-two time and also used herbicides and insecticides in their fields. Finally, on August 1-15, November 29-December 15, November 15-30, April 28–May 21 and April 11-May 3, farmers harvested their

Aus, T. *Aman*, B. *Aman* (deepwater rice), *Boro* (medium high land), and *Boro* (cultivated in the main *haor*) crops, respectively (Table 2).

Table 2. Sowing, transplanting, and harvesting date of rice cultivation in different seasons

Items	**Sowing Date**	**Transplanting Date**	**Harvesting Date**
Aus	May 6-13	May 26-30	August 1-15
T. *Aman*	July 8-15	August 15-30	November 29-December 15
B. *Aman* (deepwater rice)	May14-31	-	November 15-30
Boro (medium high land)	December 7-15	January 24-February 5	April 28 –May 21
Boro(cultivated in the main *haor*)	November 4-15	December 15-31	April 11-May 3

Source: Field survey, 2018

Inputs use pattern

Table 3 represents hectare-wise input used in the study region across various seasons. In the Sylhet region, farmers regularly hired labor on a contractual basis for the three major labor-intensive intercultural operations such as transplanting, harvesting, and carrying. In contrast, land preparation, weeding, fertilizer and insecticides application, and post-harvest processing ere done by hiring labor daily. Besides, most farmers in the *Aman* season rely on the combined harvester and power thresher for harvesting and threshing rice on a custom-hired basis. As a result, the highest number of human labor (135 man-days/ha) was used for *Boro* (cultivated in the main *haor*) cultivation followed by *Boro* (medium high land) (95 man-days/ha), *Aus* (81 man-days/ha), T. *Aman* (76 man-days/ha) and B. *Aman* (deepwater rice) (35 man-days/ha). The seed rates for *Aus*, T. *Aman*, B. *Aman* (deepwater rice), *Boro* (medium-high land) and *Boro* (cultivated in the main *haor*) were 41,44, 88, 34 and 35 kg/ha, respectively, indicating farmers used a substantially higher amount of seed than BRRI recommended rate (25 to 30 kg/ha). Farmers who cultivate rice in the deepwater ecosystem use higher seeds than in other environments. It may be because of a higher risk of damage to seeds in the seedbed and seedlings in the main field due to inundation. Except for B. *Aman* (deepwater rice) rice cultivation, on average, urea application rate was consistent with BRRI recommendation. However, the application of phosphorous fertilizer was considerably higher in all seasons compared to the BRRI recommendation. The rate of MoP application was much lower in all seasons (Table 3).

Table 3. Per hectare input use pattern in different seasons

Input item	*Aus*	T. *Aman*	B. *Aman* (deepwater rice)	*Boro* (medium high land)	*Boro* (cultivated in the main *haor*)
Human labour (man-day/ha):	81	76	35	95	135
Hired	54	55	33	73	110
Family	27	21	2	22	25
Seed (kg/ha)	41	44	88	34	35
Fertilizer (kg/ha):					
Urea	137	171	44	205	132
MoP	69	69	-	34	44
DAP	89	96	-	103	88
Gypsum	34	47	-	34	18
$ZnSO_4$	7	7	-	-	-
$MgSO_4$	3	-	-	-	-

Source: Field survey, 2018

Cultivation costs

Table 4 exhibits the per hectare cost of rice cultivation in different seasons in the *haor* area. Human labor is the most significant and most extensively used component for rice production. Per hectare, human labor costs were Tk. 44,866, Tk. 43,581, TK. 11,460, TK. 47,765 and Tk. 63,266 for Aus, T. *Aman*, B. *Aman* (deepwater rice), *Boro* (medium high land), and *Boro* (cultivated in the main *haor*) rice cultivation, respectively, which is 44.28 %, 39.57 %, 44.47%, 35.63 % and 48.59 % of the total cost of rice production in a different season, respectively (Figure 3). The result shows that per hectare *Boro* (cultivated in the main *haor*) rice cultivation required the highest labor cost. Because in the deep *haor* land covered with water hyacinth which required more labor for cleaning to prepare the land for rice cultivation. On the other hand, for broadcast, *Aman* incurred lower labor costs because right after *Boro* harvesting, farmers sow seeds directly, which also does not require land clearing, transplanting, weeding, and insecticides application.

Fertilizer cost was higher in *Boro* (medium-high land) season (Tk. 13,882/ha) followed by T. *Aman* (Tk 7,475/ha), Aus (Tk 7,042/ha), *Boro* (cultivated in the main *haor*) (Tk 5,332/ha) and B. *Aman* (deepwater rice) (Tk 792/ha). Results show that farmers usually applied all types of fertilizers on their land except in *Boro* season; on the regular land conditions, farmers applied manure, and in broadcast *Aman*, farmers only used urea fertilizer for crop cultivation. As a result, in *Boro* (medium high land), farmers incurred the highest fertilizer cost and broadcast Aman incurred the lower cost. Furthermore, farmers of the *haor* area do not apply balance doses of fertilizers. Ali, et al. (2018) also reported the same results. The reason behind this was inadequate knowledge of balanced fertilizers. The farmers in the *haor* areas do not use organic matter in rice fields. Survey results showed that the farmers applied manure only in *Boro* rice cultivation. A similar result was observed by Ahmed (1987) and Jahiruddin et al. (2009). Seed cost was higher for B. *Aman* (Tk. 3,520/ha) as it required direct seeding and a higher risk of damage to seedlings in the main field due to inundation. At the same time, seedling development costs for all seasons are nearly the same.

Irrigation cost was much higher, which is 10% of the total cost (Tk. 11,226/ha) for *Boro* (medium-high land) rice cultivation, than that of *Boro* (cultivated in the main *haor*) (Tk. 6,736/ha). On the other hand, *Aus*, T. *Aman*, and B. *Aman* cultivated in rainfed conditions. Farmers usually applied insecticides and herbicides for rice cultivation except in B. *Aman*. Because in this region, B. *Aman* is cultivated in low-lying lands that are inundated with water at the time of insecticides and herbicides application. Per hectare of insecticides and herbicides, the cost was highest in T. *Aman* (Tk. 3,154). Power-operated thresher machine is usually used for rice threshing in the study area. The cost of the threshing was Tk. 3375/ha, Tk.3000/ha, and Tk.2625/ha for both *Boro*, T. *Aman,* and *Aus*, respectively. Per hectare total variable cost of *Boro* (cultivated in the main *haor*) and *Boro* (medium high land), rice cultivation was higher in this region due to higher uses of human labor and irrigation cost.

Fixed costs do not vary with the amount of output produced (Wang 2001). The family labor, interest on operation capital, and land rental cost were considered fixed costs in this study. Farmers in the study area generally use family labor for land preparation, applying fertilizers and insecticides, monitoring irrigation, winnowing, and drying. Table 2 shows the highest family labor incurred Tk. 8,750/ha in Boro (cultivated in the main haor) and lowest in B. Aman (Tk. 900/ha). Interest on operating capital (IOC) was measured from the total variable expenditure considering the rice-growing period. For estimation, an interest rate of 10 percent a year was considered.

Table 4. Cost of rice cultivation in different seasons (Tk/.ha)

Items	*Aus*	T. *Aman*	B. *Aman* (deepwater rice)	*Boro* (medium high land)	*Boro*(cultivated in the main haor)
Variable cost					
Seedling development	2,057	2,400		2,050	2,650
Seed	2,150	2,674	3,520	1,700	1,750
Human labor	36,496	36,231	10,560	40,065	54,516
Hired labor (daily wage basis)	16,740	19,250	10,560	25,550	38,500
Hired labor (contract basis)	19,756	16,981		14,515	16,016
Tillage	6,171	7,200	600	5,478	5,292
Fertilizer	7,042	7,475	792	13,882	5,332
Urea	2,194	2,743	792	3,280	2,112
MoP	1,029	1,029		510	660
DAP	2,139	2,304		2,884	2,200
Gypsum	411	576		408	360
ZnSO4	823	823			
MgSO4	446				
Manure				6,800	
Irrigation				11,226	6,736
Herbicide	343	411		524	449
Insecticide	2,057	2,743		2,245	898
Power thresher	2,625	3,000		3,375	3,375
a. Total variable cost	67,311	62,134	15,472	80,545	80,998
Fixed Cost					
Family labour	8,370	7,350	900	7,700	8,750
Interest on operating capital @10% for five months	11,00	1,067	321	1,699	1,741
Land rent	14,000	21,000	7,050	22,500	20,700
b. Total fixed cost	23,470	29,417	8,271	31,899	31,191
c. Total cost (a+b)	82,411	91,551	23,743	1,12,444	1,12,189

Source: Authors calculation

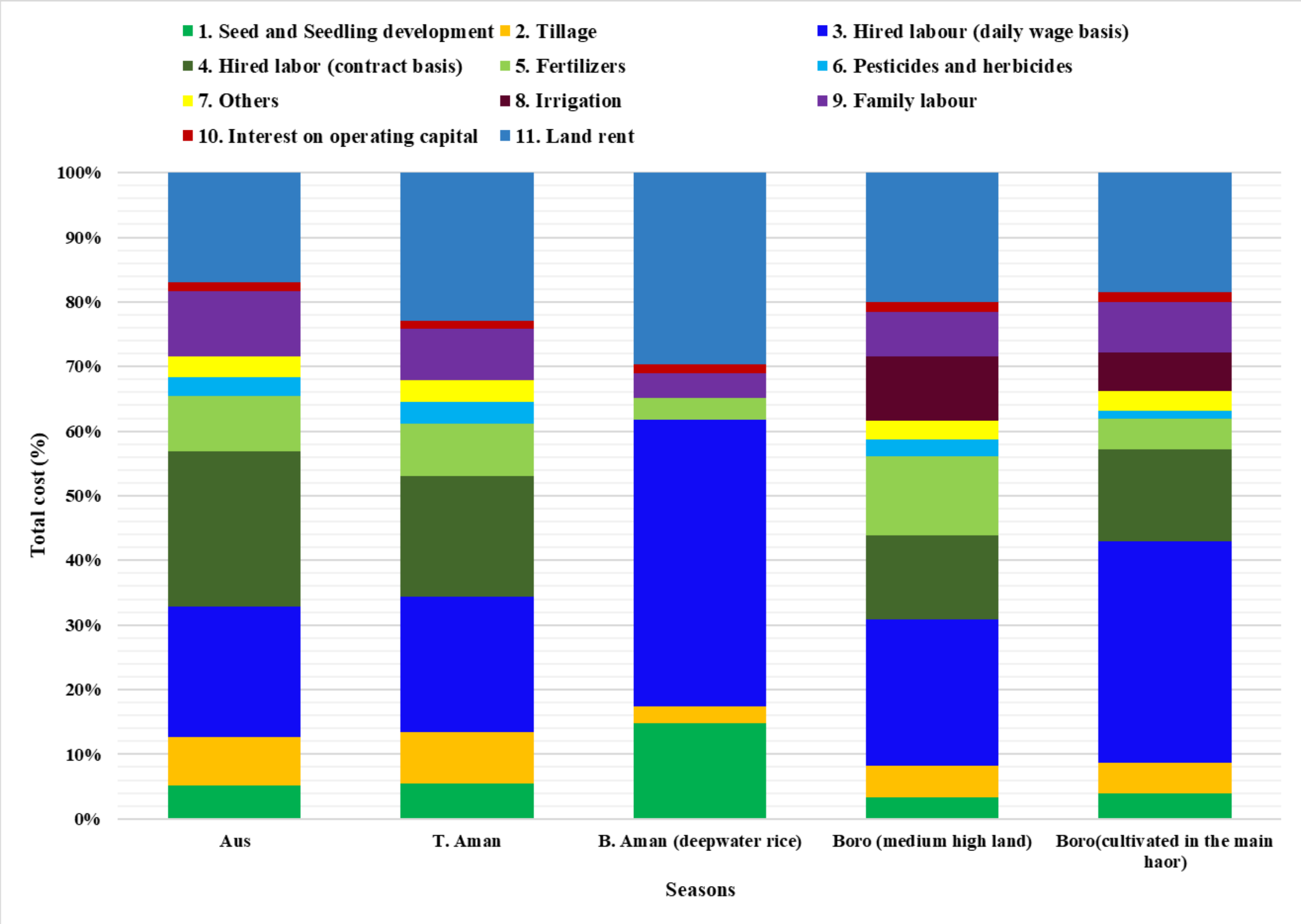

Figure 3. Representation of inputs in total cost of production in different seasons

The interest represents the total operating expenses throughout the time because not all expenses were accrued simultaneously; instead, they were utilized from start to end during the production period. Interest in operating cost for *Aus*, T. *Aman*, B. *Aman*, *Boro* (medium high land), and *Boro* (cultivated in the main haor) rice production was Tk. 1100/ha, Tk. 1067/ha, Tk. 321/ha, Tk. 1699/ha, and Tk. 1741/ha, respectively. Land rental cost per hectare varies on its productivity efficiency and season of paddy cultivation. Per hectare land rental value is the highest Tk. 22,500 for *Boro* (medium-high land) and lowest Tk. 7050 for B. *Aman*.

Farmers have spent a considerable amount of money on rice cultivation, especially in the irrigated system, where production costs were higher than in rain-fed systems. The result revealed that labor costs constituted the largest proportion of the overall expense of the variable cost (Figure 3) . This is accompanied by fertilizer, irrigation, tillage, insecticides and herbicides, power threshing, seed, and seed development. This clearly shows that large amounts of resources are invested in meeting the labor requirement. This result is substantiated by the observations made by Islam et al. (2017), Ali et al. (2019), Bawla & John (2018), and Duvvuru & Motkuri (2013) that "Rice production is labor-intensive and in most cases relies on a substantial usage of paid labor.

Profitability

Per hectare costs and return of rice cultivation in different seasons are are presented in Table 5. The yield of *Boro* (cultivated in the main *haor*) (6.57 t/ha) was the highest, followed by *Boro* (medium high land) (6.10 t/ha), T. *Aman* (4.80 t/ha), *Aus* (4.47 t/ha) and B. *Aman* (1.45 t/ha). For B. *Aman* cultivation, farmers usually used local varieties, which gives a lower yield.

Per hectare gross margin of T. *Aman* rice (Tk. 42,747) was the highest, followed by *Boro* (cultivated in the main *haor*) (Tk. 40,834), *Boro* (medium high land) (Tk. 32,755), *Aus* rice (Tk. 28,066) and B. *Aman* (deepwater rice) (Tk. 10,534) (Table 5). Farmers obtained higher returns from T. *Aman* rice due to the higher market price.

The Benefit-Cost Ratio (BCR) is a measurement tool to observe the resource use efficiency (Masum et al., 2018). Table 5 shows that BCR (undiscounted) of T. *Aman* rice, *Boro* (cultivated in the main haor), *Aus*, *Boro* (medium high land), and B. *Aman* (deepwater rice) were 1.15, 1.10, 1.07, 1.02 and 0.97, respectively. It implies that Tk. 1.15, Tk. 1.10, Tk. 1.07, Tk. 1.02, and Tk. 0.97 would be earned by investing Tk. 1.0 in producing T. *Aman* rice, *Boro* (cultivated in the main *haor*), *Aus*, *Boro* (medium high land), and B. *Aman* (deepwater rice), respectively.

Table 5. Per hectare costs and return of rice cultivation in different seasons

Items	*Aus*	T. *Aman*	B. *Aman* (deepwater rice)	*Boro* (medium high land)	*Boro*(cultivated in the main haor)
Total cost (Tk/ha):	82,411	91,551	23,743	112,444	112,189
Total variable cost	58,941	62,134	15,472	80,545	80,998
Total fixed cost	23,470	29,417	8,271	31,899	31,191
Yield (kg/ha)	4,471	4,790	1,460	6,100	6,574
Gross return (Tk/ha):	87,007	104,881	26,006	113,300	121,832
Return from paddy	84,949	99,393	23,360	109,800	118,332
Return from Straw	2,058	5,488	2,646	3,500	3,500
Gross margin (Tk./ha)	28,066	42,747	10,534	32,755	40,834
Net return (Tk./ha)	4,596	13,330	2,263	856	9,643
Unit price of grain (Tk./kg)	19	20.75	16	18	18
Unit cost of production (Tk./kg)	18.18	18.87	16.26	18.21	16.84
BCR on full cost basis	1.07	1.15	0.97	1.02	1.1

Source: Authors calculation

Therefore, the results indicated that investment in rice cultivation was profitable in current years. This finding is consistent with the results of Ali et al. (2019), and Alam et al. (2010) where they reported a positive gross margin for rice production in the *haor* area as total revenue is much higher than total variable costs. It is anticipated that the productivity of rice cultivation and certainly the farmers' profits would improve dramatically as more land is dedicated to rice production.

Determinants of the production

The findings are reported in Table 6 on the estimated Cobb- Douglas production function for rice production. Total rice output has been used as the dependent’s variable in this function. The table also presents the rice production F-value and R^2. The estimated model F-values are 4.33 and significant. It implies that all of the explanatory variables used in this analysis were necessary to understand the variations in rice production. R^2 values have been 0.81, indicating that 81 percent of the variation in rice production was explained by the explanatory variables included in the model.

The outcome revealed that most coefficients had positive signs. The coefficient of cost of seed, human labor cost, cost of TSP, cost of MoP, and cost of irrigation was found to be positive and significant at different levels. This suggests an increase of 1 percent in seed costs, human labor costs, TSP costs, MoP costs, and irrigation costs, while other variables constant will raise overall output by 0.023, 0.091, 0.151, 0.110, and 0.012 percent, respectively.

Table 6. Estimated coefficients of the Cobb-Douglas production function

Explanatory variables	Coefficients	Standard error	t-value
Constant	5.121***	1.930	2.65
Seed cost	0.023*	0.011	2.09
Human labor cost	0.091**	0.037	2.43
Land preparation cost	0.192	0.210	0.90
Urea cost	0.032	0.131	0.23
TSP cost	0.151**	0.063	2.39
MoP cost	0.110*	0.060	1.83
Irrigation cost	0.012***	0.004	3.00
Manure cost	0.019	0.013	1.46
Insecticide cost	0.007	0.023	0.30
F-value	4.322***	1.597	2.70
R^2	0.81		

*** = Significant at 1% level; ** = Significant at 5% level; * = Significant at 10% level

Constraints

A few elements commonly militate against crop development, yet each harvest has exceptional conditions that antagonistically influence its production. This could be either physiological, environmental, or the marketing of the crop (Bwala and John, 2018). During rice production, farmers in the study region were confronted with a number of challenges. This section focuses on the difficulties rice farmers in the research region encountered when cultivating rice. In haor region, the vital constraints are unavailability of labour, lower price of paddy and risk of the flash flood. Almost 100 percent of farmers agreed. The labor crisis becomes more pronounced, especially during the rice harvest, which increases labor costs. On the other hand, farmers get lower paddy prices during the paddy harvesting season since they must sell wet paddy at this time. Because they lack sufficient room to dry the rice. Furthermore, owing to excessive rains, they cannot dry the paddy, resulting in decreased paddy prices for farmers. Every year, there is a possibility of flash floods. Flash floods have decimated their crops over the years. As a result, it has been acknowledged as a significant issue by all farmers. More than 90% of farmers say that their rice farming is hindered by a shortage of high-quality modern paddy seeds, high input costs, and a scarcity of irrigation water. Almost two-thirds of farmers are concerned about the state of their transportation system. Due to poor roads, they frequently have to sell paddy at a lesser price since they can't get to the market at the right time. A shortage of appropriate varieties, adulterated fertilizers and pesticides, difficulty with credit, inadequate knowledge, and diseases and insect infestations are among the most pressing issues farmers face when it comes to rice farming in the area.

Table 7. Constraints of rice cultivation in *haor* region

Sl. No.	Constraints	Frequency (n=368)	Percentage
1	Lack of suitable rice varieties under changing climatic situation	240	65
2	Lack of availability of improved variety quality seeds	339	92
3	Scarcity of agricultural labor	368	100
4	Lower market price of paddy/rice	368	100
5	High wage rate of labor and irrigation cost	349	95
6	High price of inputs	349	95
7	Lack of irrigation facilities	202	55
8	Adulteration of inputs like fertilizers and pesticides	276	75
9	Early flash flood and lack of water control	368	100
10	Transportation problem	254	69
11	Heavy post harvest loss due to heavy rainfall	258	70
12	Increasing trend of insects and diseases infestation	239	65
13	Lack of agricultural information	166	45
14	Lack of institutional agricultural credit	147	40

Note: Multiple responses considered, Source: Field survey, 2018

Conclusion and recommendations

Rice, being a staple food for almost all of Bangladesh's population, is essential to agricultural growth and food security. Every year, the haor area produces a bountiful crop and contributes considerably to national rice output. Residents in the haor regions have several options to enhance their agricultural techniques and livelihoods.

Rice cultivation in Bangladesh is a lucrative activity; however, profit rates are slightly lower. The level of profit is significantly lower. Sampled farmers were mostly used modern high-yielding varieties for rice cultivation. For adopting a variety, socio-demographic influences had a solid and essential effect. They used a higher amount of seed than the recommended rate. On average, the farmers' rate of urea application was consistent with the recommendation. However, farmers applied a higher amount of phosphate fertilizer, while MoP was much lower in all seasons. Even though *Boro's* rice yield was higher than Aman however, *Boro's* net benefit was lower than Aman. Because *Aman* growers received higher net returns due to lower costs of production and better market prices. Farmers usually sell their paddy at the market. However, paddy traders now travel home to purchase paddy directly from farmers. The challenge of transporting paddy to the market has thus been solved. As a result, the farmers are happy at least because they do not have to carry any kind of trouble. The results of the production determinants imply that increasing the quantity of seed used, using more labour, and using more TSP, MoP, and irrigation will enhance rice output in the study area.

Farmers also identified some key problems of rice growing in the *haor* areas were higher input price, unavailability of shorter growth duration variety, and damaged flood control dams. On the other hand, dredging of rivers and canals, construction of embankment /sluice gate, reduced seasonal price variation, short duration, high yielding and stress-tolerant rice varieties, good communication, accessibility of agricultural machinery like as power tiller, irrigation gear, threshing machines, drying machines, etc and forecasting early warning system may facilitate to increasing rice production in Sylhet region.

This region's climate change scenario, particularly floods, is a major threat to sustaining rice productivity and livelihood year-round. A detailed and coordinated action plan and successful implementation strategies need to be implemented to ensure sustainable rice production in the haor region. The following recommendations are made based on the results to improve rice production at *haor*.

- Government and other research institutions should develop short-duration, high-yielding rice varieties for the *Boro* season to avoid flash floods.
- Sustainable flood control measures should be taken as early as possible, such as the embankment and dredging of rivers and canals, etc.
- Because of the higher price, farmers cannot use the inputs, i.e. seed, fertilizer, pesticides, etc. in optimum quantities. The government will then take suitable steps for the rice farmers to handle the necessary
- Ensure the availability and quality of seeds, fertilizer, diesel, and electricity as well as irrigation facilities at the beginning of the season.
- Extension service should be strengthened to raise awareness of new technologies and crop calendars. In addition to the government, the supply of farm machinery should be strengthened, and their services ensured timely.
- To reduce the sensitivity of the harvesting process and the rapid transportation of rice from risky low-lying lands, communication and transport as well as the marketing system must be improved for *haor* areas; and inputs for the rice production.

Compliance with Ethical Standards

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal.

All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

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