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ECONOMIC VIABILITY OF *BORO* RICE PRODUCTION IN *HAOR* ECOSYSTEM OF KISHOREGANJ DISTRICT

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ABSTRACT

The study was carried out to evaluate the economic viability of *Boro* rice production in *haor* ecosystem of Kishoreganj district. A total of 175 rice farmers were selected from Mithamoin upazila on the basis of farm size category following random sampling technique. Data were analyzed with a combination of descriptive statistics, mathematical and statistical techniques. It was found from descriptive statistics that average farm size of the farmers was 0.54 ha, where majority of the farmers were small category. Varietal diversity index (VDI) pointed out that most of the farmers had low *Boro* rice varietal diversity in the study area. The study revealed that *Boro* rice production was profitable and productivity index was very high. Estimates of transcendental production model indicated that power tiller and insecticides cost had significant impact on profitability of *Boro* rice production. It was exposed from the Mann-Whitney *U* test that biotic stress caused lower yield of production. Considering severity ranking model (SRM), the severity of damage was extreme for disease infestation. Following garrett's ranking technique (GRT), lower price of output, early flash flood inundation and lack of short-duration and high-yielding variety were found the major constraints faced by the farmers. The study recommended that short-duration, high-yielding and pest tolerant *Boro* rice varieties should be developed for the farmers. Therefore, proper extension services by the government are necessary to encourage farmers for adopting such technological improvements in order to produce *Boro* rice economically more viable.

Keywords: *Haor*, varietal diversity, profitability, productivity, stress

I. INTRODUCTION

Bangladesh is predominantly an agricultural country and agriculture has been the mainstay of Bangladesh economy as it comprises about 13.07% of the country's GDP and employ around 39.46% of the total labor force (BBS, 2018). Rice is the main cereal crop grown in three different seasons, namely *Aus*, *Aman* and *Boro* in Bangladesh which covers 74.85% of the total cultivable area (BBS, 2017).

Haor is a term which refers to flood prone land and other low lying areas that remain inundated with water for several months each year. *Haors* are large back swamp or bowl-shaped depressions between the natural embankments of rivers subject to

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monsoon flooding every year, mostly found in North Eastern part of Bangladesh (Alam *et al.*, 2010). The *Haor* basin comprised of large areas of seven districts, namely Sylhet, Sunamganj, Habiganj, Moulvibazar, Kishoreganj, Brahmanbaria and Netrokona covering 1.99 million ha areas of which net cultivate area is about 1.31 million ha and accommodating about 19.37 million people (MoWR, 2012). There are about 373 *haor* enveloped an area of 0.8 million ha which is around 43% of the total area (BHWDB, 2012). *Haor* in Kishoreganj district is very much important in geo-physical, economic, social and cultural point of view (Kishoreganj Zilla, 1993). Among 13 Upazillas of this district, four (*Itna, Mithamoin, Austogram* and *Nikli*) are fully bounded by *haor*. Total number of *haor* in the district is 125 with an area of 134616 hectare and these *haors* have a great significance to the agricultural production of the district (DAE, 2019). 4.42 million ton of paddy is produced in these *haor* areas (DAE, 2019). But the recent change in timing of flood and its pattern is affecting the livelihoods of the *haor* people. In addition, climatic changes have also contributed in degrading the eco-system that causes the severity of flash floods in the *haor* areas (CNRS, 2009).

The *haor* basin is an important wetland ecosystem where water remains either stagnant or in flash flooding condition during the months of June to November and mainly *Boro* rice is grown in the Rabi season using irrigation. In terms of ecosystem, crop production practices and economic activities as well as overall livelihood of the farmers of *haor* areas are quite different from those of the other parts of the country (Alam *et al*., 2010). In this area, rice cultivation is mainly dependent on the natural water although artificial irrigation is managed in some possible localities. The production of such area is confined under the choice of the nature. Sometimes the ripen rice is damaged by the uncertain floodwater in the very low areas. The *haor* is a single cropped area due to lengthy water logging condition. Almost 80% of this area (i.e. 0.68 million ha) is covered by *Boro* rice and more than 80% of the total cropped areas were practicing *Boro-Fallow-Fallow* cropping pattern (Huda, 2004). In order to have higher yield, the local farmer recently switched to cultivate HYV rice (BRRI dhan29, BRRI dhan28, etc.) instead of local *Boro* rice variety. But the longer duration and dwarf plant height characteristics of these varieties often become the victim of flash flood. As a result, farmers cannot harvest potential yield of these rice varieties (Muttaleb *et al.*, 2008).

Paddy crop is cultivated in a wide range of environments characterized by different temperatures, climates, and soil-water conditions (Basavaraj *et al.*, 2020). The crops are, therefore, exposed to various types of biotic and abiotic stresses, whose combined effect can adversely affect crop performance and survival. Biotic stresses include insect pests, fungus, bacteria, viruses and herbicide toxicity. Abiotic stresses include drought, high salinity, high or low temperatures and flooding. It is generally believed that all these stresses are considered as a serious threat to sustainable paddy production (Basavaraj *et al.*, 2020).

A few studies related to *Boro* rice production practices of *haor* people have been conducted by different researchers which are: Ali *et al.* (2019) evaluated the agro-economic performance of *Boro* rice cultivation at farmer's level of *haor* area in Bangladesh and found that productivity of *Boro* rice was low due to imbalance use of fertilizers but yield showed higher; Islam *et al.* (2018) examined the knowledge gap of the *haor* farmers in *Boro* rice cultivation and experienced that the socioeconomic characteristics of the *haor* farmers like education, farming experience and attitude towards modern *Boro* rice cultivation practices had the significant effect; Kamruzzaman *et al.* (2018) studied on flood and sustainable agriculture in the *haor* basin of Bangladesh and revealed that *Boro*-fallow-fallow was the dominant cropping pattern and flash flood severely destroy standing *Boro* rice just before harvesting almost every year; and Rahman *et al.* (2018) assessed economic investigation of BRRI dhan29 and hybrid rice production and identified that BRRI dhan29 gave higher return compare to hybrid rice in *haor* area of Bangladesh.

The above mentioned literatures clearly indicate that a number of studies have been conducted on economic prospect of rice in *haor* areas but there is lack of specific study on economic viability (profitability with risk) of *Boro* rice production considering biotic and abiotic stresses in *haor* areas. Therefore, to minimize the research gap and add valuable information on the existing notions, the study will be very helpful to the researchers as well as policy makers to recommend policy guidelines regarding the stated aspects in *haor* areas. The specific objectives of the study were: i) to examine the status of *Boro* rice production in terms of varietal diversity, profitability and productivity, ii) to assess the impact of biotic and abiotic stresses on *Boro* rice production and iii) to investigate major constraints faced by the farmers and recommend policy options.

II. METHODOLOGY

Study areas and sample size

As *haor* ecosystem, the study was conducted at four villages namely, Kuliapara, Borohaty, Islampur and Kamalpur from two agricultural blocks (Sarkarhaty and Islampur) of Mithamoin upazilla under Kishoreganj district. In the study areas, there were twenty agricultural blocks from those two agricultural blocks were selected purposively because they cover large acreage of *haor* area, bounty of *Boro* rice production and vulnerable to biotic and abiotic stresses. A total of 175 (88 from Sarkarhaty block and 87 from Islampur block) *Boro* rice farmers were selected following random sampling technique for primary data collection from the selected areas. Primary data were collected from the respondents by using a structured questionnaire during September 2019 to December 2019. Focus group discussions (FGD) and key informant interviews (KII) were also performed for data collection. Secondary data sources like reports, publications, handouts, etc., relevant with this study were also examined.

Analytical techniques

Descriptive statistics: Descriptive statistics like sum, averages and percentages were calculated to identify the farmers' socioeconomic status for producing *Boro* rice in *haor* areas.

Profitability analysis: Profitability of *Boro* rice production per hectare from the view point of individual farmer was measured in terms of gross return, gross margin, net return, and benefit cost ratio. The formulas needed for the calculation of profitability was discussed below:

$$GR = P \times Q;\ GM = GR - TVC;\ NR = GR - (TFC + TVC);\ BCR = GR \div (TFC + TVC)$$

Where,

GR = Gross return (Tk); P = Sales price of the product (Tk.); Q = Yield per hectare (metric ton); GM = Gross margin (Tk.); TVC = Total variable cost (Tk.); NR = Net return (Tk.); TFC = Total fixed cost (Tk.); and BCR = Benefit cost ratio.

Transcendental production model

In order to investigate the extent of influence of the determinants on profitability of *Boro* rice production, transcendental production model was used (Gujarati, 2003). A transcendental production model is a generalized form of Cobb-Douglas production function, which was used in this study to provide more accurate variable approximation by minimizing the stochastic errors. In the present study, the following transcendental production model was used to identify the level of influence of the factors influencing profitability of *Boro* rice production in the *haor* area:

$$Y_i = \beta_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} e^{\beta_7 X_1 + \beta_8 X_2 + \beta_9 X_3 + \beta_{10} X_4 + \beta_{11} X_5 + \beta_{12} X_6}$$

The model was made linear in the following form:

$$\ln Y_i = \ln\beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 X_1 + \beta_8 X_2 + \beta_9 X_3 + \beta_{10} X_4 + \beta_{11} X_5 + \beta_{12} X_6$$

Where,

Y_i = Net return (Tk./ha); X_1= Human labour cost (Tk./ha); X_2 = Power tiller cost (Tk./ha); X_3 = Seed/seedlings cost (Tk./ha); X_4 = Fertilizer cost (Tk./ha); X_5 = Insecticides cost (Tk./ha); X_6 = Irrigation cost (Tk./ha) and β_0 = Intercept; β_1 to β_6 = Exogenous coefficient; β_7 to β_{12} = Stochastic coefficient; and ln = Natural logarithm.

Rice productivity index: Rice productivity was measured by using Enyedi's crop productivity index. This index was used to measure the productivity of respective crops in the research area compared to the entire regions (Ogale and Nagarale, 2014). For calculation, the following formula was used:

$$\text{Crop productivity} = \left(\frac{Y}{Y_n} \div \frac{T}{T_n}\right) \times 100$$

Where,

Y = Production of the respective crop in the unit area; Y_n = Total production of the crop in the entire region; T = Cultivated unit area under the respective crop; and T_n = Cultivated area in the entire region under the respective crop.

The productivity grade was determined from the productivity range which is represented in Table 1 as follows:

Table 1: Range and grade of productivity

Range of productivity	Grade of productivity
87.5% and above	Very high
62.5% to 87.5%	High
37.5% to 62.5%	Medium
12.5% to 37.5%	Low
Below 12.5%	Very low

Source: Uddin and Dhar (2018).

Varietal diversity index (VDI): Rice varietal diversity refers to the existence of diversity of rice varieties in farmer's field (Singh *el al.*, 2000). Rice varietal diversity was measured through rice varietal diversity index (VDI). The operational definition of rice varietal diversity index (VDI) for a particular farmer was one minus of the squared sum of the proportional area planted to each variety (Kshirsagar *et al.*, 1997) and rice varietal diversity index (VDI) for a particular farmer was measured by using the following formula:

$$VDI_i = 1 - \sum_{j=1}^{n} \left(\frac{a_{ij}}{A_i}\right)^2$$

Where,

VDI_i = Rice varietal diversity index; a_{ij} = Area planted to the j^{th} variety in the i^{th} farmer; and A_i = Total area planted under rice for the farmer.

Mann-Whitney U test: To assess the significance of yield results between affected and non-affected farmers in different stresses condition, the Mann–Whitney *U* test was applied as it provided a useful non-parametric alternative to the *t* test for uncorrelated data when the data is not normally distributed (Mann and Whitney, 1947). For checking the normality condition of each group of farmers, Kolmogorov-Smirnov test (K-S test) was conducted (null hypothesis: the observations are normally distributed). The K-S test statistics (0.921682 and 0.647856 for stress affected and stress non-affected farmers) were less than the K-S critical value for both groups at 5% level of significance (0.007761). Hence, the null hypothesis was rejected, since the data for both groups of farmers were not normally distributed. The scores obtained by two individual sample farmers were ranked together, giving rank

1 to the lowest score. The ranks received by the two sets of scores obtained by two individual sample farmers were then separately summed up to obtain R_1 and R_2. To determine the value of *U*, the following formula was used:

$$U_1 = N_1 N_2 + \frac{N_1(N_1 + 1)}{2} - \sum R_1$$

$$U_2 = N_1 N_2 + \frac{N_2(N_2 + 1)}{2} - \sum R_2$$

Severity ranking model (SRM): The severity of damage of *Boro* rice production due to stress in *haor* areas was quantified and represented using severity ranking model (SRM) (Uddin *et al.*, 2018). The major consequence of the model was identified as stress. The sub-component of stress was biotic and abiotic stresses. Biotic stress of *Boro* rice farming connected with: i) insects; ii) diseases and iii) rats; and abiotic stress included: i) hailstorm and ii) flash flood. The severity of damage was characterized as extreme (severity point = 4), high (severity point = 3), medium (severity point = 2) and low (severity point = 1). The component severity score (CSS) of each stress of the model was estimated using the following formula:

$$CSS = (N_E \times SP_E) + (N_H \times SP_H) + (N_M \times SP_M) + (N_L \times SP_L)$$

Where,

CSS = Component severity score in case of diseases, insects, rats, hailstorm and flash flood; N_E = Number of farmers in extreme damage level; SP_E = Severity point of extreme damage level; N_H = Number of farmers in high damage level; SP_H = Severity point of high damage level; N_M = Number of farmers in medium damage level; SP_M = Severity point of medium damage level; N_L= Number of farmers in low damage level; and SP_L = Severity point of low damage level.

Garrett's ranking technique (GRT): Information regarding the constraints faced by the farmers in *Boro* rice cultivation was procured using garrett's ranking technique (GRT). Constraints were identified in consultation with the respondents were be asked to rank the problems proposed to them. Garrett's ranking technique provides the change of orders of constraints and advantages into numerical scores (Jimjel *et at.*, 2015). The prime advantage of this technique over simple frequency distribution is that the constraints are arranged based on their severity from the point of view of respondents. Hence, the same number of respondents on two or more constraints may have been given different rank and these ranks were entered into percent position using the formula as follows:

$$\text{Percent position} = \frac{100 \text{ X } (R_{ij} - 0.5)}{N_j}$$

Where,

R_{ij} = Ranking given to the i^{th} constraints by the j^{th} individual and N_j = Number of constraints ranked by the j^{th} individual.

The percent position was determined from the scores referring by Garrett and Woodworth (1969) which is represented in Table 2 as follows:

Table 2: Percentage positions and their corresponding Garetts table values

Rank	Percent position		Garrett table
1	100(1-0.5)/6	8.3	77
2	100(2-0.5)/6	25.0	63
3	100(3-0.5)/6	41.7	54
4	100(4-0.5)/6	58.3	46
5	100(5-0.5)/6	75.0	37
6	100(6-0.5)/6	91.7	23

Source: Garrett and Woodworth (1969).

III. RESULT AND DISCUSSION

Socioeconomic status of the respondents

The socioeconomic status of the *Boro* rice farmers depicted in Table 3 represented that average number of members in respondents' family was 5.8, which was almost 1.4 times higher compared to the country's average of 4.1 (BBS, 2016). Average farm size of the farmers was 0.54 hectare and most of the farmers (66.70%) were small category. Almost 100% male respondents were surveyed for the investigation, of which 48.6% were active and work capable as belonged to the age group of 26-50 years (lower than national average of 54.8% according to (BBS, 2016). About 46.3% respondents were have no educational level. In terms of occupation, most of the (97.7%) respondents were involved in agriculture.

Table 3: Socioeconomic characteristics of the respondents

Particulars	Percentage (%) of respondents	Particulars	Percentage (%) of respondents
Average household size (no.)	5.8	Average age (years)	
Average farm size (ha)	0.54	Below 25	3.4
Farmers' categories		26-50	48.6
Small (<1.00 ha)	66.70	Above 50	48.0
Medium (1.01-3.00 ha)	29.20	Educational level	
Large (above 3.00 ha)	4.10	Illiterate	46.3
Occupational status		Primary	33.1
Agriculture	97.7	Secondary	18.3
Others	2.3	Above secondary	2.3

Source: Field survey, 2019.

Major agronomic practices of the respondents

In *haor* ecosystem, most of the farmers (45.1% farmers) were cultivated *Boro* rice on low type of land and conversely in medium, medium low and medium high was

34.3%, 18.9% and 1.7%, respectively. The result is similar to Khan *et al.* (2010) where the authors found that there was no high land and 56.8% of farmers were used low land for rice cultivation in *haor* area. Around 52.5% farmers sown rice on clay loamy soil condition. It is seen that most of the farmers (95.4%), applied nursery seedlings and major portion of farmers (80.0%) sowed seedlings within thirty (30) days (Table 4).

Table 4: Major agronomic practices in the study areas

Particulars	Percentage (%) of respondents	Particulars	Percentage (%) of respondents
Land topography		Seedling type	
Medium high	1.7	Nursery seedlings	95.4
Medium low	18.9	Direct seedlings	4.6
Medium	34.3	Seedlings age (days)	
Low	45.1	below 30	80.0
Soil physiology		30-40	16.0
Sandy loamy	36.0	above 40	4.0
Loamy	29.1		
Clay loamy	34.9		

Source: Field survey, 2019.

Technology usage for *Boro* rice production

Boro rice production is depending on different type technology. Farmers used some technologies depicted in Table 5. It is seen that most of the farmers had low extend of average technology usage in the study area but the rate of using power threshing machine for rice threshing purpose was comparatively higher than that of other technology usage. Similar findings were also observed by Ali *et al.* (2019).

Varietal Diversity Index

Boro rice variety grown by the farmers is depicted in Table 6. It is seen that *Boro* rice variety ranged from 1 to 3 with the average of 1.71 and the standard deviation of 0.77. Majority of the farmers (68.0%) cultivated more than one variety while 32.0% farmers cultivated only single rice variety. The result is supported by Muttaleb *et al.* (2008) where the authors found that 42.16% farmers cultivated more than one variety. Farmers have been growing more than one variety due to diverse and unpredictable environment of ecosystems, diverse household needs, combat pests and diseases, suit different cropping systems and market demand (Singh *et. al.*, 2000). 48.57% of the farmers opined that unavailability of desired variety's seed as constraint of varietal diversity.

Table 5: Technology usage for *Boro* rice production in the *haor* area

Particulars	Extend of frequency (% of farmers responded)		
	High	Medium	Low
Use of power threshing machine	64.0	20.0	16.0
Use of mixed fertilizer	5.0	12.0	83.0
Use of *Guti* urea	5.0	15.0	80.0
Use of perching	46.0	28.0	26.0
Use of vermin-compost	6.0	24.0	70.0
Straw retaining on the crop land	15.0	24.0	61.0
Average technology usage by the farmers	23.5	20.5	56.0

Source: Field survey, 2019.

Table 6: Distribution of number of *Boro* rice varieties grown by the farmers

Rice variety (no.)	Percentage (%) of respondents	Mean	Standard deviation
1	32.0		
2	48.0	1.71	0.77
3	20.0		

Source: Field survey, 2019.

Boro rice variety cultivated by the majority (38.9%) of the farmers was BRRI dhan28 (Table 7) and at the same time 32.6, 26.9 and 1.6% of farmers planted BRRI dhan29, Hira dhan and Lota *Boro*, respectively. In respect of area coverage, BRRI dhan28 ranked first covering with 37.35 percent cultivated area followed by BRRI dhan29 (35.90%) and Hira dhan (25.05%). The results implied that high yielding varieties occupied a vast majority area (73.25%) than local and other varieties. Khushi *et al.* (2018) indicated that HYV rice is essential to encourage more farmers to produce rice.

Table 7: Distribution of *Boro* rice varieties of the farmers along with area (%) and rank order

Variety	Respondents		Varietal coverage	
	(% of respondents)	Rank order	Area (%)	Rank
BRRI dhan29	32.6	2	35.90	2
Hira dhan	26.9	3	25.05	3
BRRI dhan28	38.9	1	37.35	1
Lota *Boro*	1.6	4	1.70	4

Source: Authors' estimation, 2020.

Table 8 outlines that diversity index of variety ranged from 0 to 0.89 with the average of 0.33 and the standard deviation of 0.55. Farmers were classified into four categories viz. no, low, medium and high varietal diversity index. It is found that the highest proportion (48.0%) of the farmers had low *Boro* rice varietal diversity while 32.0%, 17.1% and 2.9% had medium, no and high *Boro* rice varietal diversity, respectively. Thus, overwhelming majority (97.1%) of the farmers had no, low and medium *Boro* rice varietal diversity index while Muttaleb *et al.* (2008) indicates 96.08% of the farmers had no, low and medium rice varietal diversity and that was lower than this finding. Varietal diversity provides different growth duration with diverse characters that may reduce or escape the risk of rice crop damage due to early flash flood, hailstorm, severe wind, pests, diseases, drought and other natural hazards (Bellon *et al.*, 1998).

Table 8: Distribution of respondents according to *Boro* rice varietal diversity index

Particulars		Percentage (%) of respondents	Range	Mean	Standard deviation
Diversity categories	No (0)	17.1	0-0.89	0.33	0.35
	Low (0.01-0.33)	48.0			
	Medium (0.34-0.66)	32.0			
	High (>0.66)	2.9			

Source: Authors' estimation, 2020.

Profitability of *Boro* Rice Production

Boro rice is the major crop in the *haor* areas and almost all the farmers produce this crop. Table 9 represents that 48.07% of total cost was incurred for human labour hiring purpose which was almost similar to Rahaman *et al.* (2018) where the authors found that 49.89% of total cost was considered for labour cost. BCR from *Boro* rice production was found as 1.22. The results imply that farmers could earn Tk. 122 by investing Tk. 100 in *Boro* rice production. Therefore, it can be concluded that *Boro* rice production is profitable in the study areas. This finding is supported by Rasha *et al*. (2018) where the authors found *Boro* rice production was profitable.

Table 9: Cost-return analysis of *Boro* rice production

Particulars	(Tk./ha)	Percentage (%) of total cost
Variable cost		
Information on seedbed		
Seed	2984.1	4.16
Seedling production (bed preparation, fertilizer, insecticides, irrigation)	1813.7	2.53
Total cost of preparing seedbed	4794.8	6.68
Information on main land		
Power tiller	5371.0	7.48
Labour related information		
Land preparation and transplantation of seedling	10851.8	15.12
Intercultural operation (fertilizing, weeding, insecticide spray, etc.)	5008.0	6.98
Harvesting, threshing, drying and storing	18637.0	25.97
Total labour cost	34496.8	48.07
Information on fertilizer, herbicide, insecticide and irrigation application		
Chemical fertilizer	8293.6	11.56
Organic fertilizer	2352.6	3.28
Herbicides	58.2	0.08
Insecticides	350.0	0.49
Irrigation	8000.1	11.15
Total cost of fertilizer, herbicide, insecticide and irrigation application	19054.5	26.55
i. Total variable cost	63717.3	88.78
Fixed cost		
Land use cost	6458.0	9.0
Interest on operating capital (10% of interest rate)	1592.0	2.22
ii. Total fixed cost	8050.0	11.22
iii. Total cost (i+ii)	71767.3	100.0
Return items		
iv. Gross return (Tk./ha)	87303	
v. Gross margin (Tk./ha) (iv-i)	23585.7	
vi. Net return (Tk./ha) (iv-iii)	15535.7	
vii. Benefit cost ratio (BCR) (iv÷iii)	1.22	

Source: Authors' estimation, 2020.

Factors Affecting Profitability of *Boro* Rice Production

A production function relates physical/monetary value of output of a production process to physical/monetary value of inputs or factors of production (Felipe and

Fisher, 2003). In this study, a transcendental production model was used conveying the determinants influencing profitability of *Boro* rice production in *haor* area. Since the cost of human labor, power tiller, seed/seedlings, fertilizers, insecticides and irrigation cost are the major factors that affect *Boro* rice production in the *haor* areas (Uddin *et al.*, 2018), only these six variables were considered as explanatory variables for this model.
The estimated equation was as follows:

$$\ln Y_i = 25.78 - 0.001\ln X_1 + 0.0026\ln X_2 + 0.0015\ln X_3 - 0.0061\ln X_4 + 0.070\ln X_5 - 0.0024\ln X_6 + 0.344X_1 - 1.557X_2 + 0.496X_3 + 0.144X_4 - 0.434X_5 - 0.271X_6$$

Table 10: Estimates of transcendental production model

Variables	Exogenous coefficients	p-value	Stochastic coefficients	p-value	Value of R^2	F-value
Intercept	25.78	0.0039				
Human labor cost (X_1)	-0.0010	0.551	0.344	0.479		
Power tiller cost (X_2)	0.0026*	0.091	-1.557**	0.042		
Seed/seedlings cost (X_3)	0.0015	0.185	-0.496	0.369	0.365	30.26
Fertilizers cost (X_4)	-0.0061	0.408	0.144	0.834		
Insecticides cost (X_5)	0.070*	0.090	-0.434*	0.072		
Irrigation cost (X_6)	-0.0024	0.603	-0.271	0.517		

Source: Authors' estimation, 2020.
Note: ** and * indicate significant at 5% and 10% probability level, respectively.

The exogenous estimates of transcendental production model indicate that power tiller cost, seed/seedlings cost and insecticides cost had positive impacts; while human labour cost, fertilizers cost and irrigation cost had negative impacts on profitability of *Boro* rice production (Table 10). Among the identified determinants, power tiller cost and insecticides cost were found to have significant impact on profitability of *Boro* rice production. The value of coefficient of determination (R^2) was found as 0.365 which implied that 36.5 percent variation of dependent variable has been explained jointly by the independent variables, i.e., the model is well fitted. The F-value of 30.26 meant that all of the explanatory variables included in the model were important to explain the variation of the dependent variable. The model shows a decreasing returns to scale (=0.064) which means that the outputs will increase in a lower rate compared to the rate of increase in all production inputs.

Measurement of *Boro* Rice Productivity

Productivity is the ratio between input and output in agriculture, where input refers to land, labour, production value of crops and output refers market value of producing crops (Singh, 1966). In this study, *Boro* rice productivity was estimated using the enyedi's crop productivity index which can measure land productivity to evaluate yield rate of *Boro* rice production. It is seen that *Boro* rice productivity was estimated at 100.36%, which imply that farmers could get 100.36 percent of output by applying all inputs in the study area (Table 11). The result is relatively higher compare to (Uddin et *al.*, 2018) where the authors observed that productivity of crop was 86.4%.

Table 11: *Boro* rice productivity index

Particulars	Index values	Productivity grade
Production in the unit area (metric ton/ha)	3.90	
Total production in the entire region (metric ton/ha)	682.74	Very high
Cultivated unit area (ha)	0.54	
Cultivated area in the entire region (ha)	94.88	
Index of productivity (%)	100.36	

Source: Authors' estimation, 2020.

Impact Evaluation of Stress on yield of *Boro* Rice Production

The deviation of *Boro* rice yield between affected and non-affected farmers by different stress (biotic stress: disease, insect and rats; abiotic stress: flash flood and hailstorm) condition is depicted Table 12. The study found that stress affected farmers were getting lower yield (32.2% and 25.8%) than stress non-affected farmers due to disease and insects infestation, respectively (significant at 1% of probability level). This finding is supported with Islam et *al.* (2018) where the authors observed that *Boro* rice yield lowering about 58% due to lack of fertilizer and pest management knowledge.

Table 13 reveals the severity ranking of stress of the *Boro* rice farmers in *haor* areas. It was observed that the level of damage was the highest considering for disease infestation which was ranked as 1st (with CSS 587). It was followed by insects (with CSS 544), rats (with CSS 274), hailstorm (with CSS 284) and flash flood (with CSS 322) ranking as 2nd, 5th, 4th and 3rd, respectively. The result is connected with Alam *et al.* (2010) where the author showed that early flood, hailstorm and drought are the main constraints to grow modern *Boro* rice.

Table 12: Impact evaluation of stress on yield of *Boro* rice

Particulars	Stress categories									
	Biotic stress						Abiotic stress			
	Disease		Insects		Rats		Flash flood		Hailstorm	
	A	NA	A	NA	A	NA	A	NA	A	NA
Yield (Kg/ha)	2692	5256	2942	4946	3454	3613	3496	4336	3504	4045
Yield difference	32.2% lower for affected farmers		25.8% lower for affected farmers		2.0% lower for affected farmers		10.7% lower for affected farmers		7.2% lower for affected farmers	
Mann-Whitney *U* test										
z value	-7.796***		-2.629***		-0.509		-0.915		-0.935	
p value	0.0000		0.0086		0.6110		0.3602		0.3498	

Source: Authors' estimation, 2020.
Note: A=Affected and NA=Non-affected.

Table 13: Severity ranking of stress of the *Boro* rice farmers

Particulars	Severity of damage (number of respondents)					
	Extreme	High	Medium	Low	Severity score	Severity rank
Biotic stress						
Disease	112	27	22	14	587	1
Insects	80	53	23	19	544	2
Rats	10	13	43	109	274	5
Abiotic stress						
Hailstorm	14	8	51	102	284	4
Flash flood	15	30	42	88	322	3

Source: Authors' estimation, 2020.
Note: Severity points: Extreme = 4, High = 3, Medium = 2, and Low = 1.
Calculation of severity score for disease = (112 × 4) + (27 × 3) + (22 × 2) + (14 × 1) =587.
Calculation for other stresses was done accordingly.

Constraints Faced by the Respondents

Applying Garrett's ranking technique (GRT), it was from the Table 14 found that the major constraints experienced by the farmers cultivating *Boro* rice in *haor* areas are the low price of paddy (69.56), early flash flood inundation (65.78), lack of short-duration and high-yielding variety (65.25), high price of inputs (fertilizers, insecticides, pesticides, etc.) (63.72), lack of proper training and extension support (56.89) and Lack of storage and transportation facilities (53.49).

Table 14 Ranking constraints associated with *Boro* rice production in the *haor* area

Factors	Rank						Total farmers	Total score	Total mean	Rank
	1	2	3	4	5	6				
Early flash flood inundation	97	36	14	9	12	7	175	11512	65.78	2
High price of inputs (fertilizers, insecticides, pesticides, etc.)	86	35	20	11	15	8	175	11152	63.72	4
Lack of short-duration and high-yielding variety	85	40	26	10	12	2	175	11419	65.25	3
Low price of paddy	122	24	10	9	6	4	175	12174	69.56	1
Lack of storage and transportation facilities	30	18	48	57	12	10	175	9362	53.49	6
Lack of proper training and extension support	42	28	60	20	16	9	175	9957	56.89	5

Source: Authors' estimation, 2020.

IV. CONCLUSION

The study concludes that majority of the farmers' possessed low varietal diversity in the study areas. Though producing *Boro* rice was found as moderately profitable, the net return could be augmented with more investment on power tiller, seed/seedlings and insecticides costs. *Boro* rice productivity was very high which resulted in a significant impact on economic prospects of *haor* farmers, since the opportunity of producing other profitable crops was very limited to them. The study exposed that although flash flood was the common phenomena for disruption of rice production in the *haor* areas, massive infestation of disease and insect in recent times caused lower yield of *Boro* rice production. Considering the findings of the study, some essential policy recommendations have been arisen which are: i) short- duration, high-yielding and pest-tolerant rice varieties should be developed for the farmers considering the *haor* agricultural environment; ii) research on exploring proper disease and insect control methods by both chemical and biological means is necessary; and iii) government should motivate farmers through proper extension services to adopt such technological advancements for producing *Boro* rice economically more viable in the *haor* areas.

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