The Bangladesh Journal of Agricultural Economics, 46(2): 28-46, 2025

EFFECTS OF STRESS SEVERITY ON FARMERS' ADJUSTMENT STRATEGIES AND FOOD SECURITY: EVIDENCE FROM *BORO* RICE FARMERS IN THE *HAOR* ECOSYSTEM OF BANGLADESH

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OPEN ACCESS

ARTICLE INF

Received: 9 Dec 2025
Accepted: 20 April 2026
Published: 06 May 2026

Keywords: Stress Severity, Farmer Adjustment Strategies, Food Security and Haor areas

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ABSTRACT

The Haor ecosystem is a hotspot of environmental vulnerability where natural hazards, ecological sensitivity, and livelihood dependence converge to enhance exposure to agricultural and food security problems. This study analyzed stress severity, coping strategies, and food security scenarios and their determinants among Boro rice producers in the flood-prone haor area of Bangladesh. A multistage random sampling method was used to select 180 farmers from three haor areas: Kishoreganj, Netrokona, and Sunamganj. Descriptive statistics, index, and logit models were used to achieve the study objective. Boro rice cultivators experienced submergence as the most severe stress (CSS, 655; normalized CSS 0.91), whereas flash floods (CSS 604; Normalized CSS 0.84) and heavy rainfall (CSS 544; Normalized CSS 0.76) were the second and third severest stresses, respectively, indicating that abiotic hazards are predominant. Among the biotic factors, insects (CSS 578; Normalized CSS 0.80, rank 3) and diseases (CSS 567; Normalized CSS 0.79, rank 4) were the most severe, whereas rats (CSS 276; Normalized CSS 0.38) and birds (CSS 215; Normalized CSS 0.30) had the lowest severity. In general, the order of severity reveals that extreme pre-monsoon weather is the most harmful to Boro rice productivity. Farmers in the haor region made multiple adjustment strategies for coping with water stress caused by floods, and the creation of waterways near the field was the highest in preference (Adjustment Index = 0.000280). Drainage systems were second (0.000153) because they are functional for fast water discharge. In contrast, interventions such as setting up machinery for the early evacuation of flood water were less adopted (0.000003) owing to financial constraints and restricted practical viability. Several socioeconomic factors were significantly associated with HHFS in the study area. On the other hand, household head's age and dependency ratio had negative significant effects on food security, while education, farm size, and access to credit all had positive and significant effect in improving food security. Off-farm income and food aid availability had no significant impact, whereas crop diversification had a weak contribution. Overall, the model had a good fit in explaining most determinants of household food security. In general, these responses revealed that farmers depend on low-cost, locally customizable waterlogging mitigation measures.

https://doi.org/10.70133/bjae.2025.498
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I. INTRODUCTION

Bangladesh has experienced significant advancements in its economic, social, and health situations, with an annual GDP growth rate of 5.82% (WB 2023). Health and nutrition outcomes have improved significantly. Although the nation's overall conditions are auspicious, the people residing in haor areas are relatively poor. Haor people are poor, less educated, and vulnerable, struggling to meet basic needs, especially during floods. Inadequate food is a significant issue, highlighting their challenges compared to mainland populations, as they rely heavily on agriculture for survival (Islam and Afrin, 2025). Haor is a low-lying river basin situated beneath the floodplain level, akin to swamp land inundated for nearly six months annually, commencing with the monsoon (Sharma 2010; Uddin et al., 2025). The haor regions of northeastern Bangladesh span over 2.0 million hectares and house approximately 19.4 million inhabitants. Approximately 373 haors are situated throughout seven districts, encompassing an area of roughly 858,000 ha, which constitutes approximately 43% of the total expanse of the haor region (MoWR, 2012). The ecosystem, agricultural production methods, economic activities, and overall livelihoods of farmers in haor regions differ significantly from those in other areas of the country (Alam et al., 2010). Natural calamities are gradually intensifying due to climate change, posing risks to haor people. People living in these areas face insecure livelihoods due to the impacts of climate change, which cause significant vulnerability. Haors are single-cropped areas where flash floods cause crop damage, which is considered a significant threat to people. Many people in the haor areas are involved in fish capture (Rahman & Salam, 2008). Small-scale livestock keepers are also threatened as major victims of the changing climate and its impact. Haor people endure a very insecure livelihood because of biotic and abiotic stresses. The diminishing cropped land area is a barrier to increasing output. Consequently, harnessing the agricultural potential of the haor regions, which are typically underutilized and exhibit low cropping intensity, is essential (Jabber & Alam, 1996). Malnutrition is prevalent among wetland community-dwelling older adults in Bangladesh, with 59.75% malnourished. Factors include low health literacy, poor diet, and health conditions, making them more vulnerable to diseases and physical decline. (Rahman et al., 2022).

Several studies pertaining to the modality of the present research have been conducted by various researchers. For example, Hoq et al. (2022) analyzed the determinants of household livelihood diversification strategies against natural hazards in the ecologically at-risk haor region of Bangladesh. They identified that the age and education level of household heads, size of land holdings, annual income, and distance of home from the road are influential factors for opting for higher return value adding livelihood diversification strategies. Baten and Hossain (2021) studied the determinants of perception and impact of climate change-induced events among the people in the haor region of Kishoreganj and found that climate change caused floods, which is a major barrier to constructing flash flood prevention dams. The economic viability of Boro rice cultivation in the haor ecosystem of the Kishoreganj district was studied by Kamruzzaman and Uddin (2020), who reported that the production of Boro rice was profitable with a very high productivity index. Uddin et al. (2018) discussed the haor market opportunities and barriers in Bangladesh, with highly significant differences in quantities and prices of inputs as well as products between haor sites and mainland. Islam et al. (2018) reported on the information deficiency of haor farmers in Boro paddy farming and found that their socioeconomic attributes have significantly affected outputs. Uddin et al. (2018) explored the impacts of farming practices and living conditions in haor areas, where most farmers practiced crop-livestock-fish capture farming system with frequent exposure to the disasters. Khan et al. (2012) investigated the impact

of floods on crop production in haor areas and reported that Boro rice in the Rabi season was affected by flash floods as there were no control measures. Islam et al. (2011) conducted an economic analysis of various farming systems in the Dingapota haor area of Netrokona district, concluding that rice was the sole crop cultivated by farmers, occupying approximately 70 percent of the total cropped area.

Considering the importance of haors in the socioeconomic development of Bangladesh and ensuring food security for haor people, it is essential to increase agricultural production and attain higher cropping intensity. The importance of this research lies in assessing the condition of crop intensification among at-risk haor farmers and their productivity, which contributes to poverty alleviation and enhances food security for the haor farming community, ensuring inclusiveness. To fill this gap, the current study has the following aims that are consistent with the research need: i) to document the stress severity faced by the haor farm households; ii) to identify their adjustment strategies against different stresses, iii) to determine the drivers of farm households' food security and suggest policy recommendations for intensifying haor agriculture, ensuring farm households' food security, and promoting their adjustment strategies.

II. MATERIALS AND METHODS

2.1 Study area

The study areas were selected from three upazilas of three districts, namely, Austagram upazila under Kishoreganj district, Netrokona upazila under Netrokona district, and Sunamganj upazila under Sunamganj district, considering the bounty of crop diversity and the severity of different stresses.

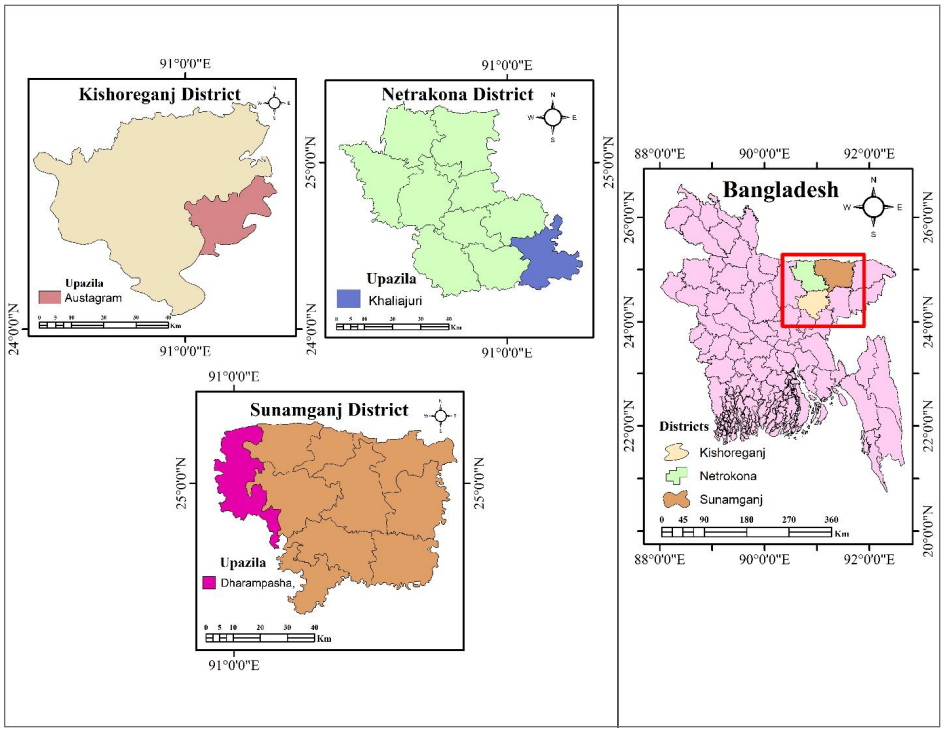


Figure 1: Map of the study area

2.2 Sampling techniques and sample size

The multistage stratified random sampling technique was used to select the respondent farmers. A total of 180 farmers, 60 from each district, were interviewed for this study.

2.3 Method of data collection

A field survey method was used to collect primary data from the sample farmers using a structured and pre-tested questionnaire. Focus group discussions (FGD) were also conducted to collect group information and cross-check the data and information.

2.4 Statistical analysis

Descriptive statistics (i.e., sum, average, percentage, ratios, etc.) were used to document the socioeconomic characteristics of the *haor* farm households.

2.5 Analytical technique

2.5.1 Component of stress severity score

The intensity of biotic and abiotic pressures on *haor* agriculture was measured and depicted by a severity ranking model used by Uddin *et al.*, 2018. The component severity score (CSS) for each stressor in the model was calculated using the subsequent 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 of severity score

N_E, N_H, N_M, N_Lrepresent the number of farmers reporting extreme, high, medium, and low levels of damage, respectively. $SP_E, SP_H, SP_M, SP_L$are the corresponding severity points assigned to each damage level (Extreme = 4, High = 3, Medium = 2, Low = 1).

To allow comparison across different stressors and study areas, the CSS was normalized by the maximum possible score:

$$CSS_{normalized} = \frac{CSS_{observed}}{CSS_{max}}$$

Where,

$CSS_{\max} = N \times SP_E$and N is the total number of respondents. The normalized CSS ranges from 0 to 1, providing a standardized measure of stress severity across the study areas.

2.5.2 Farmers' adjustment index

Farmers' adjustment index used by Uddin et al., 2017 was employed to document the strategies adapted by the *haor* farm household as follows:

$$\text{Farmers adjustment index} = P_{vl} \times P_l \times P_m \times P_g \times P_{vg}$$

Where:

P_{vl}= proportion of farmers with very low adjustment
P_l= proportion of farmers with low adjustment
P_m= proportion of farmers with medium adjustment
P_g= proportion of farmers with good adjustment
P_{vg}= proportion of farmers with very good adjustment
Each proportion was calculated as:

$$P_i = \frac{n_i}{N}$$

Where:
n_i= number of farmers in adjustment category i
N= total number of sampled farmers
The FAI therefore reflects the joint distribution of farmers across all five adjustment categories.

2.5.3 food security index

The farmers' food security index (Z) was developed to assess food security status. Food security status of each household was determined based on the food security line using the recommended daily calorie intake (Babatunde et al., 2007). For ease of exposition the equation was written as follows:

$Z_i = Y_i \div R$

Where,

Z_i = Food security index for the i^{th} household

(1= food secure households and 0= food insecure household, i.e., $Z_i = 1$ for $Y_i \geq R$; $Z_i = 0$ for $Y_i < R$);

Y_i = Daily per capita calorie intake of i^{th} households;

R = Daily per capita calorie required for i^{th} households and i=1, 2, 3, ……..,n.

Head count ratio (H) measures the percentage of households that are food secure or insecure (Maharjan and Chhetri, 2006), which can be measured as follows:

$H = M \div N \times 100$

Where,

H = Head count ratio;

M = Number of households that are food secure or food insecure; and

N = Number of sample households.

2.5.4 Logit regression model

The Binary Logistic Regression Model (BLRM) is employed to analyze the influence of independent variables on farmers' food security. This method enabled us to evaluate the extent to which independent variables impacted the likelihood of adopting mechanized harvesting (Hosmer *et al.*,1989; LaValley *et al.*, 2008). According to Kundu *et al.*, (2024) the model was chosen for this study because it avoided linear interactions with the explanatory variables and ensured that the estimated probability ranged between 0 and 1. As stated below, the cumulative logistic distribution function serves as the basis for the model.

$$P_i = E\left(Y = \frac{1}{X_i}\right)\alpha + \beta_1$$

$$P_i = E\left(Y = \frac{1}{X_i}\right)\alpha + \frac{1}{1 + e^{-z}}$$

Where, Pi = Probability of food security.

The log of odd ratio or logit is

$$Logit\ (Z_i) = \frac{\{The\ probability\ of\ food\ security\}}{\{The\ probability\ of\ food\ insecurity\}} = \alpha + \beta_i X_i + U_i$$

For ease of exposition

$$Z_i or Y_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ \ldots\ldots + \beta_n X_n + U_i$$

A dichotomous response variable, Y_i (dependent variable), is required to obtain Z_i. In the Binary Logistic Regression Model, the dependent variable represents farmers' food security, coded as 1 for food secure and 0 for food insecure**,** reflecting the binary nature of the response variable. To

evaluate food security, the model included eight explanatory variables. These were the explanatory variables that were specified:

X_1 = Age of household's head (years)
X_2 = Educational level of household's heads (years of schooling)
X_3 = Dependent family members
X_4 = Farm size (ha)
X_5 = Availability of credit (1=yes, 0=no)
X_6 = Off farm income (1=yes, 0=no)
X_7 = Access to food aid (1=yes, 0=no) and
X_8 = Crop diversification; (1= diversified, 0=non-diversified)
U = error term

III. RESULTS AND DISCUSSION

3.1 Socioeconomic profile of the farmers

Table 1 shows the demographic profiles of the farmers in Kishoreganj, Sunamganj, and Netrokona. The mean age of farmers in all areas was 44.9 years, parallel to the national rural mean age of 45 years (BBS, 2022). The highest mean was 47.6 years, reported in Sunamganj, and the lowest was observed in Netrokona (40.6 years). Occupational patterns varied considerably across the regions. Kishoreganj demonstrated a very high reliance on agriculture (80%), whereas in Netrokona, 62% were involved in agriculture as well as other activities, thus providing greater diversification of income. Salam and Bauer (2022) also demonstrated that nonfarm income has a huge impact on the rural economy of Bangladesh and provides a major share of household income and poverty alleviation. The lowest figure was found in Kishoreganj (88.3% illiterate), and the highest in Netrokona (only 13.3%). Sunamganj has moderate literacy levels. Farmers are predominantly young and middle-aged with mostly primary-level education, indicating a relatively low formal educational background among practitioners in flood-prone areas (Sarker et al., 2025). Farm size also differed significantly. The average landholding was the highest in Sunamganj (2.75 ha), followed by Kishoreganj (1.92 ha) and Netrokona (1.11 ha).

Table 1: Socioeconomic characteristics of the respondents

Items	Kishoreganj	Sunamganj	Netrokona	All areas
Sample size	60	60	60	180
Farmer's age (year)	46.6	47.6	40.6	44.9
Occupation (%)				
Agriculture Only	80	50	38	56
Agriculture and others	20	50	62	44
Level of education (%)				
Illiterate	88.3	26.7	13.3	43
Primary	8.3	55.0	56.7	40
Secondary	1.7	13.3	15.0	10

Items	Kishoreganj	Sunamganj	Netrokona	All areas
Higher Secondary or above	1.7	5.0	15.0	7
Farm size (ha)	1.92	2.75	1.11	1.93

Source: Field survey, 2025

3.2 Primary farming approaches followed in the *haor* areas

The distribution of the major farming systems in the three *haor* upazilas of Kishoreganj, Sunamganj, and Netrokona is considered in relation to integrated activities concerning crops, livestock/poultry, and fish capture (Table 2). Of the surveyed houses, the Crop–Livestock–Fish capture (C–L–F) system was the most prevalent and embraced by 46.11% of farmers. It dominated particularly in Sunamganj (53.33%), followed by Kishoreganj (45.00%) and Netrokona, 40.00%.

Table 2: Major farming practices in the study areas

Farming system	Kishoreganj		Sunamganj		Netrokona		All areas	
	No. of farmers (n=60)	Percentages (%) of farmers	No. of farmers (n=60)	Percentages (%) of farmers	No. of farmers (n=60)	Percentages (%) of farmers	No. of farmers (n=180)	Percentages (%) of farmers
Crop-Livestock-Poultry (C-L-P)	10	16.67	8	13.33	7	11.67	25	13.89
Crop-Livestock-Fish capture (C-L-F)	27	45.00	32	53.33	24	40.00	83	46.11
Crop-Poultry-Fish capture (C-P-F)	17	28.33	15	25.00	20	33.33	52	28.89
Crop-Livestock-Poultry-Fish capture (C-L-P-F)	6	10.00	5	8.33	9	15.00	20	11.11

Source: Field survey, 2025

In *haor* livelihoods situated in northeastern Bangladesh, inland fish capture is still a keystone activity, while seasonal wetlands provide opportunities for natural fisheries that contribute to strengthening rural livelihoods and nutritional diversity (Pandit et al., 2023). Al Mamun (2011) observed that "with more recent integration of fish into livestock and crop, there has been an improvement in both fertilizer and feed supplies as well as a high market value of fish as one part, making the crop–livestock–fish system increasingly attractive to small farmers".

The C–P–F system (C–Crop; P–Poultry; F-Fish) was followed by 28.89% of the farmers, particularly by 33.33% in Netrokona, mainly because it uses low-cost poultry manure as pond fertilizer and does not demand a lot of labor or infrastructure, thus being highly accessible to smallholders (Alam et al., 2009). However, the low adoption of Crop–Livestock–Poultry (C–L –P) (13.89%) is ascribed to the high risks associated with disease proliferation and labor input for

those who would incorporate poultry into a livestock enterprise without the buffering role played by aquaculture in waste management (FAO, 1992). Lastly, the fully diversified C–L–P–F model was used by only 11.11% of farms, consistent with national surveys indicating a low rate of crop-fish poultry integration due to high management demands and cross-sector expertise (Rahman et al., 2023).

3.3 Level of stress severity among *boro* rice farmers

Table 03 reveals how farmers perceived the importance of different biotic and abiotic stresses in the *Boro* rice area during the study period. Farmers responses were classified into four levels: high, medium, low, and extreme, to arrive at the total severity score and rank each of these stressors (Figure 02).

Table 3. Measurement of stress severity of the respondents

Particulars	Severity of damage (number of respondents)							
	Extreme	High	Medium	Low	Severity score	Maximum Score	Normalized CSS	Rank
Biotic Stress								
Disease	75	69	24	12	567	720	0.79	4
Insects	77	74	19	10	578	720	0.80	3
Rats	3	14	59	104	276	720	0.38	7
Birds	0	0	35	145	215	720	0.30	8
Abiotic Stress								
Flash flood	102	55	8	15	604	720	0.84	2
Hailstorm	25	43	52	60	393	720	0.55	6
Heavy rainfall	58	83	24	15	544	720	0.76	5
Submergence	123	50	6	1	655	720	0.91	1

Source: Authors' estimation, 2025.

Note: Severity points: extreme = 4, high = 3, medium = 2, and low = 1.

The severity score for submergence was calculated as follows: (123 × 4) + (50 × 3) + (6×2) + (1×1) = 655. The calculations for the other stresses were performed accordingly.

Among abiotic stresses, submergence was the most severe, with a severity score of 655 (normalized CSS 0.91) and ranked first. Empirical evidence from coastal and char land areas of Bangladesh also confirms that climate-induced stresses and limited access to improved technologies significantly reduce crop productivity and farm income (Kundu et al., 2026; 2022). Flash flooding occurred shortly after (CSS 604; Normalized CSS 0.84), as well as heavy rainfall which also presented major problems (CSS 544; Normalized CSS 0.76), demonstrating that the pre-monsoon season is indeed inordinate to the agricultural cycle. Hailstorms (CSS 393; Normalized CSS 0.55) were less important, but insects (CSS 578; Normalized CSS 0.80, rank 3) and diseases (CSS 567; Normalized CSS 0.79, rank 4) had economically significant effects on crop productivity, especially during tillage and planting.

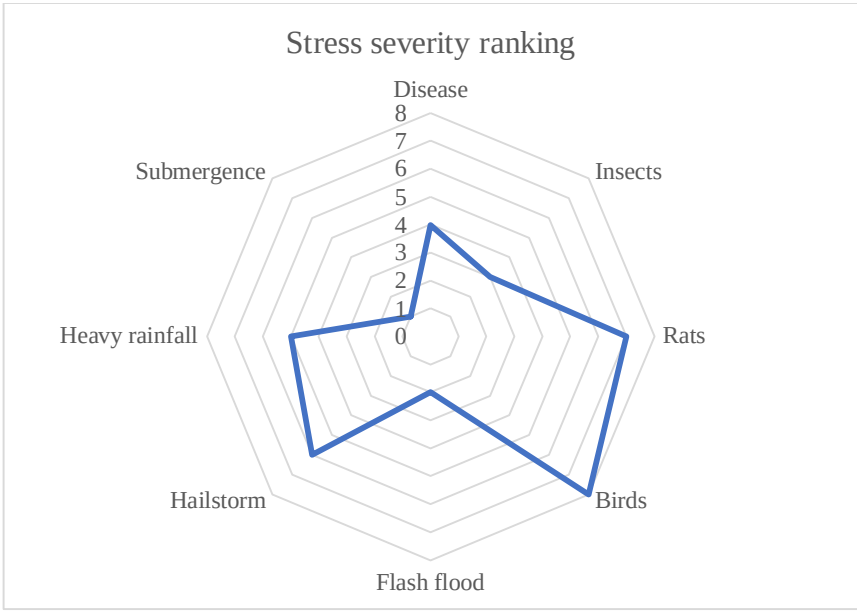


Figure 2: Ranking of Stress Severity Among *Boro* Rice Farmers

Rats (CSS 276; Normalized CSS 0.38) and birds (CSS 215; Normalized CSS 0.30), by comparison, had the lowest feeding score values (seventh and 8th position, respectively), indicating a modest effect on crop loss, presumably due to a controlled population or effective deterrents put in place by farmers. The study conducted by Sultan et al. (2018) showed that unanticipated submergence and flash floods during the pre-monsoon season were the most serious abiotic constraints to *Boro* rice, followed by unpredictable heavy precipitation. With regard to the latter water-logged scenario, insect pests (e.g., stem borer, leaf folder) and fungal diseases (e.g., blast, sheath blight) were seen as moderate biotic challenges of concern, while rodent and bird damage were classified as minor owing to the effective local control measures in place.

3.4 Farmers adjustment strategies in the *haor* areas

Farmers in wet farming systems practice various soil and water management techniques to control waterlogging in their fields and ensure crop health. Making a waterway adjacent to the agricultural field ranked highest (Adjustment Index = 0.000280), reflecting its broad applicability for diverting excess water (Table 4). Alam et al., (2017) found that peripheral field channels reduced ponding depth by over 40% in seasonal wetlands of northern Bangladesh that significantly improving aeration in rice root zones. Similarly, Ayers and Westcot (1985) demonstrated that simple open channels expedite runoff, preventing hypoxic stress in submerged crops.

Table 4: Farmers adjustment index

Strategies	Percentage (%) of respondents					Adjustment Index	Rank
	Very Good (5)	Good (4)	Medium (3)	Low (2)	Very Low (1)		
Rapid harvest readiness	0.04	0.06	0.06	0.45	0.38	0.000025	10
Arrange machines for early flood water removal.	0.82	0.07	0.06	0.03	0.03	0.000003	13
Pre-season land preparation	0.04	0.09	0.27	0.32	0.28	0.000087	3
Threshing site setup	0.06	0.36	0.43	0.18	0.04	0.000067	4
Flood control maintenance	0.02	0.06	0.29	0.34	0.28	0.000033	7
Quick drainage construction	0.19	0.37	0.13	0.24	0.07	0.000153	2
Make a waterway adjacent to the agricultural field	0.15	0.26	0.16	0.28	0.16	0.000280	1
Make small ponds around fields	0.49	0.34	0.06	0.06	0.06	0.000036	5
Raising of the field surrounding	0.37	0.44	0.13	0.04	0.02	0.000017	11
Elevated nursery management	0.03	0.03	0.32	0.38	0.24	0.000026	9
Use farm implements in different ways	0.03	0.04	0.17	0.48	0.27	0.000026	8
Early-sown varieties adoption	0.04	0.05	0.12	0.27	0.52	0.000034	6
Short-cycle crop use	0.02	0.04	0.07	0.33	0.54	0.000009	12

Source: Authors' estimation, 2025.

Note: The adjustment strategy score for rapid harvest readiness was calculated as follows: $(8\div180) \times (11\div180) \times (11\div180) \times (81\div180) \times (69\div180) = 0.000025$. The calculations for the other adjustment strategies were performed accordingly.

The second most practiced approach was to create quick drainage construction to alter the flood height shape (Adjustment Index = 0.000153), which is consistent with Okwany et al. (2016) who stated that the shallow tile drains placed in flat delta soils reduced water tables by 50 cm within

48 h of flood receding, resulting in prompt and adequate soil tillage and operations. However, interventions such as "Prepare machines for early floodwater removal" (ranked 13th with an Adjusted Index of 0.000003) have a low uptake, possibly because they are not considered feasible in the *haor* areas. High capital costs, fuel requirements, and maintenance impediments limit pump use in remote *haor* villages (Devkota, 2014).

3.5 Food frequency of the farm household in the study area

Table 5. reveals the consumption patterns of various food groups among the respondents, reflecting dietary preferences and food accessibility. Rice, pulses, and vegetables, which are consumed in large quantities, were consumed thrice a day by 58.33% of the participants, twice a day by 32.22% of the participants, and once a day by 9.44% of the participants, with no participant not consuming all of these. Over 30% of the respondents consumed vegetables/pulses twice or more per day in rural Bangladesh, and vegetables/pulses are evident as major sources of calorie and nutrient intake (Haque et al., 2014). On the other hand, foods eaten with moderate frequency, such as fish, meat, eggs, and dairy, were mostly consumed two times per day (73.89%); only 11.67% were consumed once a day, and 14.44% were consumed thrice a day, which implied that occasional intake might be influenced by household affordability or frequency of availability.

Table 5: Measurement of Food consumption frequency among the farm household

Foods	Not consumed during a whole day (%)	Consumed once a day (%)	Consumed twice a day (%)	Consumed three times in a day (%)
Highly consumed food (rice/wheat, pulses, vegetables, leafy vegetables, etc.)	0	9.44	32.22	58.33
Moderately consumed foods (fish, chicken/mutton/beef, eggs, milk, tea/coffee, fast food, etc.)	0	11.67	73.89	14.44
Less consumed foods (fruits, sweets, juice/drinks, cakes/cookies, cream/chocolate, honey, etc.)	72.78	25.56	1.11	0.56

Source: Field survey, 2025

It is common knowledge from the evidence across South Asia that approximately 70–75% of rural households eat fish, meat, milk, or eggs twice a day, and only around 10–12% can afford to have them once a day, and not more than 13–15% have them in three meals (FAO, 2019). Fruits, sweet, and processed items were the least consumed, with 72.78% of respondents not consuming them at all in a day, 25.56% consuming them once during the day, and less than 2 % respondents consuming them more than once.

3.6 Level of food security among the farm households

Table 5 shows the food security status of the sampled farmers disaggregated by farm size and indicates a clear relationship between farm size and household food security. Among the farm household types, large agricultural households showed absolute food security with the significantly highest mean calorie intake (2838.31 kcal) and Food Security Index score (1.19). and none are food insecure. Reynolds et al. (2019c) also discovered that larger farms in rural China consumed more than 2800 calories/day of food per adult equivalent on average, which they associated with more diversified production and improved market access. Barrett (2010) also shows that farm size is positively related to dietary diversity and sufficiency of calories, since larger landholdings enable HHs to allocate plots to both staple and high–value crops, thus reducing seasonality in food availability. Households belonging to medium farm households also had positive results, with food secure households averaging 2700.08 kcal and an index of 1.13. This observation accords with the findings of Smith and Subandoro (2007) who found that medium-scale farms in this subcontinent were about 10–15% more likely than smallholders to reach the target calorie consumption, owing to self-production and surplus sales that support household purchasing power.

Table 5: Measurement of Food security of farm households

	Food-secure household				Food-insecure household			
Farm Size	**% of farmers**	**Average calorie intake**	**Food security index value**	**Head count ratio**	**% of farmers**	**Average calorie intake**	**Food security index value**	**Head count ratio**
Small	37.22	2573.56	1.08		23.33	1908.58	0.80	
Medium	22.78	2700.07	1.13	0.64	12.22	2267.22	0.95	0.36
large	4.44	2838.31	1.19		0.00	0.00	0.00	

Source: Authors' estimation, 2025.

Recommended per capita daily calorie intake (R) is 2393 kilocalories

In contrast, small farm families are highly vulnerable. A considerable proportion (23.3%) was below the food security level, with a daily average intake of only 1908 kcal and an index value of 0.80. This finding is consistent with Maxwell and Wiebe's (1998) conclusion that smallholders frequently face shorter-duration fallow cycles and limited resource endowments leading to chronic underconsumption. In general, the headcount ratio is 0.64 for food secure and 0.36 for food insecure households, which is in line with global estimates that suggest that approximately one-third of agrarian HHs in low-income countries are below the dietary energy requirement (FAO, 2020). This evidence emphasizes the crucial relationship between farm size and food security.

3.7 Determinants of food security in the *haor* areas

Based on the logit regression analysis, there are some statistically important factors that determine household food security in the study areas (Table 6). The effective age of the head of the household had a negative and significant impact on food security (coefficient = -0.132, $p = 0.000$), suggesting that elderly heads are less likely to experience higher food security, which may be attributed to their diminishing physical strength and having few choices in terms of livelihood diversification. Uddin et al. (2024) document that elderly-headed households are often reluctant

to adopt new practices and face limited livelihood options. On the other hand, education has a positive and significant effect (coefficient=0.239, *p*-value=0.007), indicating that more educated households have a higher ability to secure food, probably due to knowledge and skills as well as better access to opportunities. The positive effect of education is strongly supported by Khandoker et al. (2016) who show that higher educational attainment significantly improved information access, efficiency, resource and production outcomes. The coefficient for the number of dependent family members is also significantly negative (-0.203, $p = 0.039$) meaning food insecurity increases as a function of the dependency ratio, since it has been assumed that there would be more pressure on household resources, with less available to ensure that its members were well-fed. Dessie et al. (2022) and Mamo et al. (2024) demonstrated that high dependency ratios strain household resources and increase food insecurity risk. Farm size had a positive and significant relationship (coefficient = 0.705, $p = 0.001$), which means that households with a larger area of land were more food secure because of their higher production potential and capacity for income generation. The substantial positive effect of farm size is consistent with the findings of Kadir and Prasetyo (2023), Ruslan and Prasetyo (2023), and Mensah et al. (2021) confirming that larger landholdings improve production capacity and income.

Credit availability is one of the most important determinants, exhibiting a highly significant and positive coefficient (coefficient = 2.725, $p = 0.000$). This implies that credit access plays an important role in enhancing household food security by facilitating investment in agriculture, purchasing necessary inputs, and consumption smoothing in the face of external shocks. The strong and significant credit effect is consistent with Kundu et al. (2026) and Khatun et al. (2014), who found that credit positively influences technology adoption, agricultural productivity, and overall household welfare in rural areas. These off-farm earnings have a positive but statistically insignificant impact (coefficient = 0.584, $p = 0.258$), suggesting that while non-agricultural income might improve food security, it is an inconsistent or small amount of the variation within the sample.

Table 6: Estimation of the coefficients of food security determinants

Particulars	Coefficient	Std. err.	z	P>|z|
Age	-0.132	0.03	-4.39	0
Education	0.239	0.089	2.69	0.007
Dependent family members	-0.203	0.098	-2.07	0.039
Farm size	0.705	0.219	3.22	0.001
Availability of credit	2.725	0.54	5.04	0.000
Off farm income	0.584	0.516	1.13	0.258
Access to food aid	-0.363	0.509	-0.71	0.476
Crop diversification	0.934	0.524	1.78	0.075
Constant	3.447	1.47	2.35	0.019
Number of observations	180			
Log likelihood	-56.753845			
LR chi2(13)	121.95			
Prob > F	0.0000			
Pseudo R2	0.5179			

Source: Authors' estimation, 2025.

Similarly, access to food aid has a negative but not statistically significant relationship (coefficient = -0.363, p = 0.476), suggesting that food aid alone does not lead to better food security, perhaps because the households that receive aid are already more vulnerable. Crop diversification has a positive coefficient (0.934) and is weakly significant at the 10% level (p = 0.075), indicating that food security responds positively to diversified cropping households, but not enough to surpass typical comparative thresholds associated with significance levels. Finally, the significant positive coefficient for crop diversification is supported by Derso et al. (2024) who documented improved food and nutrition security with greater crop diversity.

The specification works for the model, with a log-likelihood of –56.75 and a likelihood ratio chi-square value of 121.95, both of which indicate that the overall model predicts better than one based on random chance (p = 0.0000). The pseudo-R^2 value of 0.5179 demonstrates an explanatory potential of approximately 52% in variability for household food security by the predictors in this study, which indicates strong explanation abilities on cross-sectional data.

IV. CONCLUSION AND RECOMMENDATIONS

The study showed that *Boro* rice growers in the *haor* area are exposed to major abiotic and biotic stresses, and submergence, flash floods, and excessive rainfall are highly threatening for production. Cropping performance is also greatly influenced by biotic stresses such as insects and diseases; however, rodents and birds have a relatively low impact. Socioeconomic factors (age, dependency ratio, education, farm size, and access to credit) have the strongest effect on household food security, while off-farm income, food aid, and crop diversification have a limited or marginal effect. Farmers use a variety of strategies to adjust to waterlogging, where on-site, low-cost, and locally viable measures, such as developing boundary watercourse networks and

outflow channels, are more predominant than high-cost interventions, including early floodwater withdrawal machinery. Taken together, these results highlight the interplay between environmental stress, household abilities, and adaptive strategies in determining resilience and food security in flood-dominated *haor* ecosystems.

To enhance food security and resilience among *Boro* rice farmers in the *haor* region, policymakers should prioritize low-cost, locally adaptable water management strategies, such as constructing field-adjacent waterways and drainage systems, along with support for resilient and short-duration crop varieties. Strengthening access to credit, farmer education, and training can improve adaptive capacity and informed decision-making, while early warning systems for submergence and flash floods can enable timely interventions. Additionally, subsidizing feasible mechanized solutions for floodwater removal would increase the adoption of effective coping measures, reduce vulnerability, and promote sustainable agricultural productivity in these flood-prone ecosystems.

Conflict of interest: The authors declare that there is no conflict of interest.

Acknowledgement:

The author thanked the Bangladesh Agricultural University Research System (BAURES), BAU, Mymensingh-2202 which provided funding for the study. The research was conducted under the project titled "*Haor* Agriculture in Bangladesh: Perspective of Crop Intensification, Stress Severity and Food Security (Project No. 2023/1927/BAU)".

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