Determinants of households' livelihood diversification strategies to adapt with natural disasters: Evidence from ecologically vulnerable haor region of Bangladesh

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Abstract

The *haor* region of Bangladesh is exposed to a variety of natural disasters such as flash floods, seasonal floods, droughts, riverbank erosions, embankment breaches due to climate change, which impacts the *haor* people's lives and livelihoods. The study aims to assess the various livelihood strategies adopted by the *haor* households, as well as the factors that influence their decision to pursue more environmentally friendly and sustainable livelihood strategies. The primary data from the 300 *haor* households in Kishoregonj, Netrokona and Sunamgonj districts were collected with a multi-stage stratified random sample technique taking 100 of each district. We provide inimitable insight into the analysis framework for understanding sustainable rural livelihood, as well as empirical evidence of how livelihood resources, livelihood strategies, and livelihood outcomes are strongly interrelated. The study classified households' economic activities into five distinct categories together with crop farming to cope with natural disasters. Among the livelihood options, crop plus livestock rearing is the most productive livelihood strategy for *haor* households. The findings revealed that the higher returning livelihood diversification strategies are significantly influenced by the household's head age and education, dependency ratio, land holdings, household assets value, access to credit, annual income, membership of any organization, home to road, market, and *haor* distances, communication during the dry season, duration of waterlogged, and agro-ecology. In order to change the local context and enable poor households to establish more profitable livelihood strategies, policies should aim to promote the significant determinants of livelihood strategies, as well as ensure livelihood assets, a strong infrastructure, and minimize natural disasters.

1 Introduction

Agriculture has suffered globally as a result of natural disasters due to climate change. Rural livelihood in wetlands (*haor*^[1]) of Bangladesh is mainly dependent on agriculture. Agriculture-based livelihood is vulnerable to the effect of several nature-induced disasters such as flash floods, floods, droughts, riverbank erosions, and embankment damage especially in the *haor* ecosystem of Bangladesh (CIRDAP 2016; Ferdushi et al. 2019; Ahmad and Afzal 2020). Pre-monsoon heavy and intense rainfall in April and May causes flash floods in the northeastern region of Bangladesh, and during the monsoon, the region receives too much water due to excessive rainfall that typically begins in June and causes seasonal flooding. Riverbank erosions and embankment breaches are associated with the onrush of the river water during flash floods and seasonal floods (Hoq et al. 2021a). Droughts, on the other hand, are caused by insufficient rainfall during the dry season (Toufique and Islam 2014; Kamal et al. 2018; Salam et al. 2021). Over the years, climate change has appeared as a threat to the natural life and livelihood of the *haor* community (Rahman et al. 2018a). The *haor* delta of Bangladesh is lying below the northeastern Himalayan foothills very often faces heavy rainfall which causes flash floods and monsoon floods every year (Sarker et al. 2014; Alamgir et al. 2020). There are altogether 423 *haors* spread over seven northeastern districts of Bangladesh (Alam et al. 2010; Kamruzzaman and Shaw 2018), which are geographically isolated and ecologically vulnerable (Rabby et al., 2013; Seventh Fifth Year Plan, 2015-2020) and comprised an area of about 2.0 million hectares and accommodated about 19.4 million people (Sharma 2010; Kamruzzaman and Shaw 2018; Uddin et al. 2019). More than 28% of the population in the *haor* areas lives below the poverty line which is significantly higher than the national average (20.5%) of Bangladesh (BBS, 2019). Natural disasters are the main causes of poverty, which are aggravated by the inaccessibility of basic infrastructure and social services, inequity in resource acquisition, and poor access to natural resources (Parvin and Akteruzzaman 2012). These nature-induced climatic events and inconvenience intensify environmental degradation in developing countries, particularly in Sub-Saharan Africa, South Asia, and the Pacific (Rahut et al. 2014, 2017; Gebru et al. 2018; Abera et al. 2021). Even in developed countries like Central America and the United Kingdom, smallholder farmers are vulnerable to the negative effects of climate change, which has had a significant impact on crop production because smallholder farmers rely on it for both subsistence and income (Donatti et al. 2019; Wheeler and Lobley 2021). Therefore, as a developing country like Bangladesh, where agriculture plays a vital role in the economy by providing subsistence and income to a large portion of the society, climate change effects pose a serious economic risk, particularly to the inhabitants of such agro-ecology susceptible to the natural hazard (Bhowmik et al. 2021; Ferdushi et al. 2019). Therefore, livelihood diversification strategy is fairly important to adapt with the vulnerability of these natural disasters (Roy and Basu 2020; Zhou et al. 2021), as it is predominantly a risk management strategy; both adaptation of climatic shocks and coping after definite shocks (Pelling 1999; Ellis 2000; Brouwer et al. 2007; Gebru et al. 2018; Ahmad and Afzal 2020; Adnan et al. 2021). Livelihood strategy comprises the household's capabilities, income activities, and assets holding (natural, physical, human, financial, and social) that contribute to a means of living (Chambers and Conway 1992; Islam et al. 2013; Rahman and Hickey 2020). Rural households combine a diverse set of economic and social activities, which construct a portfolio of livelihood income-generating activities to meet and enhance sustainable rural livelihood outcomes (Davis et al. 2010; Jiao et al. 2017; Khatiwada et al. 2017; Uddin et al. 2018; Pagnani et al. 2020). According to Ellis (1998) livelihood diversification is a process where household member constructs a diverse set of activities to help them fight for their survival and improve their living standards. Rahut et al. (2014) showed the majority of rural households in rural Nepal perceive more than one activity or income source for their livelihood. Gebru et al. (2018) also found that farm households engaged in a diverse set of off-farm and non-farm activities to cope with climate change in the eastern Tigray region of Ethiopia. Due to the risk and uncertainty in agricultural production, farm income alone could not feed the ever-increasing population (Gebru et al. 2018). Consequently, an alternative way of increasing income during the lean period of farming is to find out that could be involved in various non-farm activities which will facilitate the farm households' to lead a good life (Parvin and Akteruzzaman 2012). Amare and Simane (2017) pointed out that smallholder farmers in the Blue Nile basin of Ethiopia adopt livelihood diversification as an adaptation strategy to climate change and variability. Uddin et al. (2021) also proposed a livelihood strategy approach for post-disaster risk management in coastal Bangladesh. Empirical research reveals that five livelihood strategies along with crop farming were pursued by the household in Rural Cambodia (Jiao et al. 2017), Nepal (Rahut et al. 2014), and Bhutan (Rahut et al. 2017) in different agro-ecological settings. In this study, livelihood diversification refers to the attempts by individuals and households to find new ways rather than a single activity to raise incomes and reduce vulnerability to different livelihood shocks in *haor* areas. The wetlands have various ecological, economical, and commercial importance to the residents as they are rich in biodiversity having rich flora and fauna (Kamruzzaman and Shaw 2018). The unwavering natural resources are land, forest, and water in the *haor* areas (Rana et al. 2009). Natural grazing land (grassland) and large water basins are made available to the *haor* community for income-generating, livestock rearing, and fisheries activities (Rana et al. 2009; Rabby et al. 2013). Despite the economic importance, the people in this region are poorer than in any other part of the country. However, agriculture (mainly rice cultivation) is

highly seasonal farming in the *haor* areas of Bangladesh (Khan and Islam 2005; Gautam and Andersen 2016; Blackmore et al. 2021). During winter, paddy is produced with minimum effort while during monsoon the same is turned into a water basin which is a breeding place for fishery and a wide range of water biodiversity (Sheuli 2017). Generally, monsoon is the lean season for agriculture because all infrastructures, including road networks in the *haor* areas, are submerged for about 6-7 months (BHWDB 2012; CAN 2017). Therefore, this season offers a window of opportunities to the *haor* household to have interaction in several farms or off-farm activities i.e. fishing, poultry raising (mainly duck raising), and off-farm activities like wage laborer, boating, and small scale business for sustaining their livelihood (Islam et al. 2012; Rabby et al. 2013; Gautam and Andersen 2015; Trina et al. 2015; Alam et al. 2017; Akter et al. 2020). Different livelihood diversification strategies require a different level of investment and offer differential earnings. The poor households are less likely to get involved in higher returning sectors as it demands higher capital (human, social or financial capital) investment to start up (Gautam and Andersen 2016). As the majority of the *haor* households are living below the poverty line, it is crucial to explore and develop an in-depth understanding of the causes of poverty and vulnerability issues in the *haor* areas and how they manage their day to day activities as a part of the process of attempting to secure a sustainable livelihood. Previous study outside from Bangladesh consistently showed that diversification to the non-farm sector improves farm household incomes, enhance food security, and boosts agricultural productivity by reducing capital constraints and assisting in the management of environmental hazards (Barrett et al. 2001; Davis 2014; Loison 2015; Gebru et al. 2018). Livelihood activities of the *haor* household traditionally included irrigated *boro* rice cultivation, combined with homestead vegetable gardening, livestock rearing, fishing, poultry farming, and off-farm income activities i.e. small business, boating, day laborer (agricultural and non-agricultural), and household work as sources of subsistence (Hoque et al. 2018; Islam et al. 2016a; Islam et al. 2016b). *Boro* rice is grown on 80% of the *haor* areas, and it is frequently harmed by early flash floods, hailstorms, and drought (Alam et al. 2010; Ali et al. 2019). The flood risk is a great hazard for *boro* rice cultivation which trends to food insecurity of *haor* households because *boro* rice is the foremost source of year-round food supply for their livelihood (Ferdushi et al. 2019; Kabir et al. 2020). Fish culture is the second most important livelihood strategy after crop farming (rice) in Bangladesh and its production contributes to the livelihoods and employment of millions of people (Islam et al. 2012; Sunny 2017). Another lucrative livelihood strategy of *haor* household is livestock rearing in the *haor* areas during the dry season as it has large grazing land (Islam et al. 2016c). Due to ecological and geographical difficulties, the monsoon in the *haor* area is not suitable for livestock rearing. But during monsoon, duck rearing is a profitable option for the *haor* household because of the ecological support (Islam et al. 2016c). Homestead duck and chicken eggs are available in the local market and they earn a considerable amount of cash income for their livelihood (Huque et al. 2011). So, adopting context-based livelihood diversification strategies could be able to meet the present challenges of diversification, thus attaining household food security and improving livelihood security (Abera et al. 2021; Gebru et al. 2018). Most previous studies focused on the different issues, such as socioeconomic status, cropping patterns, livelihood vulnerability to flooding (i.e., livelihood exposure and sensitivity), and adaptation perspectives of the *haor* household, which justified the rationale for the study to be undertaken (Basak et al. 2015; Dewan 2015; Rahman et al. 2018b; 2018c; Uddin et al. 2019; Hoq et al. 2021a). Only a limited number of studies were conducted on livelihood strategies and most of them concentrated on a single practice (Trina et al. 2015; Islam et al. 2016b; 2016c; Sunny 2017). Despite the significance of these studies, questions about how frequently and under what socioeconomic conditions diversification can take place remain unanswered. As a result, the focus of this research is to fill that gap by combining all possible livelihood strategies that can lead to livelihood diversification.

[1] A *haor* is a wetland ecosystem that physically is a bowl or saucer shaped shallow depression.

2 Materials And Methods

2.1 Description of the Study area

The research was carried out in the *haor* areas of Bangladesh, which are situated in the northeastern part of the country. The *haor* region's climate is subtropical monsoonal, with an annual rainfall of around 4,000 mm. The monsoon season, which runs from June to October, yields almost 80% of the rainfall. Pre-monsoon temperatures range from 26°C to 31°C (March to May), rainy season temperatures range from 28°C to 31°C, and winter temperatures range from 26°C to 27°C (Banglapedia 2003). The *haor* areas are spread over seven districts of Bangladesh; Sunamganj, Habiganj, Moulvibazar, Sylhet, Kishoreganj, Netrokona, and Brahmanbaria. Three dense *haor* districts (Kishoreganj, Sunamganj, and Netrokona) were purposively chosen from seven *haor* based districts and two administrative sub-units of each district (Upazila) were selected from each district, giving priority to the core *haor* area. The six administrative sub-units (Upazila) were Itna and Mithamoin in Kishoreganj, Khaliajuri and Mohonganj in Netrokona, and Dera and Salla in Sunamganj district (Fig. 1).

2.2 Determination of sample size

A total of 300 *haor* households with 100 from each district were surveyed from six Upazilas in three districts to collect primary data for reaching the study's objectives. Based on the household size of each Upazila, 50 potential farmers were selected from the union level (local level administrative unit) given priority for an equal distribution of six Upazila. The sample size was determined by following the given formula by Kothari (2004)

$$n = \frac{p * (1 - p) * Z^2}{e^2} (1)$$

Where n is the sample size and P is the estimated proportion of respondents, 0.5 was used as a p-value to get a maximum number of the respondents. Z denotes the amount of standard error in the 95% confidence interval, which is 1.96, and e denotes the margin of error that the researchers are willing to accept, which is 0.06.

$$n = \frac{0.5 * (1 - 0.5) * 1.96^2}{0.06^2} = 266 \approx 300$$

Therefore, a complete of 300 households was selected from five livelihood strategy group (Table 1). The sample household picked proportionally from each livelihood strategy group.

Table 1
Livelihood strategies of the sample household

Livelihood strategy group	Total households in the surveyed unions of six Upazila (N)	Sample household (n)	Percent
Group Y1: Only crop farming	7361	102	34
Group Y2: Crop + Livestock farming	3753	52	17
Group Y3: Crop + Fish farming	3392	47	16
Group Y4: Crop + Poultry farming	3248	45	15
Group Y5: Crop + Off-farm activities	3897	54	18
Total	21651	300	100
(Source: Survey data, 2020)			

2.3 Data sources and data collection procedure

This study relies on farm-level primary data collected from September 2019 to March 2020, with secondary information used only to compare the research findings. A pre-tested, semi-structured questionnaire was used to collect primary data from 300 *haor* households. Secondary data obtained from earlier research into the subject helped the researcher better understand the research area, shaping the research approach and identifying gaps that need to be filled by the research. Secondary information on relevant issues was gathered from various published sources, such as the Bangladesh Bureau of Statistics (BBS), the Upazila Agricultural Office (UAO), the Department of Agricultural Extension (DAE), and many others. Face-to-face interviews were conducted with the household head by trained enumerators with Bangladeshi linguistic communication (Bengali) for collecting primary data.

2.4 Sampling technique and sampling procedure

Multi-stage stratified sampling technique was used to select study location and sample households. In the first stage of sampling, the study locations were selected purposively, keeping in the mind of the geographical location and core *haor* area. The second stage involved the identification of five livelihood strategy groups, which was mostly practiced by the *haor* household. The numbers of sample households from each group are determined proportionately based on total household's number in the respective group. Finally, required numbers of sample households were selected randomly from each livelihood strategy group.

2.5 Analytical framework to understand sustainable rural livelihood

The sustainable livelihood concept is gradually important in the development context. The Sustainable Livelihood Framework (SLF) offers a strategy to reduce poverty through investigating the lives of poor people (Agarwala et al. 2014). The capabilities, tangible and intangible assets, and activities are needed to make a living can be defined as a livelihood. It will be called sustainable when it can survive with and recover from shocks and stress, and uphold its capabilities and assets, including the natural resource both presently and in the future. The sustainable livelihood framework (Fig. 2) is useful for determining whether people's livelihoods are sustainable in terms of three key aspects (Khatiwada et al., 2017; Carney, 1998; Soltani et al., 2012; Babulo et al., 2008). These are livelihood assets (human, natural, physical, financial, and social capitals), as well as mediating factors, livelihood diversification strategies, and outcomes that work together. However, the three aspects of the SLF are livelihood platform, livelihood strategy, and outcome (Fig. 2). Human, natural, physical, financial, and social capitals are the five categories of a household's assets highlighted by the SLF. Households combine these assets together with activities and choices and construct a portfolio of activities (such as crops, livestock, poultry, fisheries, etc.) to achieve their livelihood goals which can be defined as livelihood strategies. Households' livelihood strategy choice is influenced by its asset holding and external factors such as geographical location and infrastructure. This study also used household asset holding, geographical location (agro-ecology, waterlogging), and infrastructure (proximity to road and market center, communication system, etc.) as conditioning factors for livelihood strategy choice (Tesfaye et al., 2011; Soltani et al., 2012). Livelihood outcomes are the gains from livelihood strategies (such as income, food security, poverty reduction, environmental sustainability, etc.)

2.6 Empirical Econometric model to understand determinant of livelihood strategy

When the dependent variable has more than two choices, multinomial logistic regression (MNL) is a popular and widely used model for nominal outcomes (Wulff 2014). According to Green (2003) when the dependent variable has more than two alternatives from which the decision-maker must choose (i.e., unordered qualitative) the appropriate econometric model is either multinomial logit or multinomial probit regression. However, due to the estimation difficulties imposed by the need to solve multiple integrations related to multivariate normal distributions, multinomial probit is rarely used in empirical investigations. Therefore, a multinomial logit model was used in the study to determine the factors that influence a *haor* household's decision to participate in various livelihood strategies (Abera et al. 2021; Gebru et al. 2018; Amare and Simane 2017). This model was chosen not only for its computational simplicity, but also for its greater ability to anticipate livelihood diversification and differentiate between rural households' livelihood strategies (Amare and Simane 2017). The dependent variables of the multinomial logistic regression are polytomous and allow more than two discrete outcomes. It can be used

to analyze socioeconomic and physical explanatory variables empirically. A logical household head selects one of five livelihood strategy that provides the most utility. Assume for the i^{th} respondent faced with j choices, we specify the utility choice j as:

$$U_{ij} = Z_{ij}\beta + \epsilon_{ij} \quad (2)$$

U_{ij} is the highest of the j utility values if the respondent prefers choice j . As a result, for j selection, the statistical probability model is:

$$\text{Prob}(U_{ij} > U_{ik}) \text{ for all other } k \neq j \quad (3)$$

Where,

U_{ij} represents the utility of the i^{th} respondent from j^{th} livelihood strategy and U_{ik} represents the utility of the i^{th} respondent from k^{th} livelihood strategy.

If a household's utility is calculated in terms of income realizations, then its option is simply an optimal allocation of its assets endowment to select a livelihood that maximizes its utility (Brown et al. 2006). Thus, the decision of the i^{th} household can be modeled in terms of optimizing expected utility by selecting the j^{th} livelihood strategy from a set of J discrete livelihood strategies, thus the choice function is:

$$\max_i = E(U_{ij}) = \int (x_i) + \epsilon_{ij}, j = 0, \dots, J \quad (4)$$

If the i^{th} household chooses the j^{th} livelihood strategy to maximize its utility, the value could be 1 if the i^{th} household chooses the j^{th} livelihood strategy and 0 for otherwise. Thus, the probability of i^{th} household with x characteristics of j livelihood strategy are:

$$P_{ij} = \frac{\exp(X_i\beta_j)}{\sum_j \exp(X_i\beta_j)}, j = 0, \dots, J \quad (5)$$

With the requirement that $\sum_j P_{ij} = 1$ for any i

Where;

P_{ij} = Probability of i^{th} respondent's chance of falling into category j ,

X = Predictors of response probabilities and

β_j = Covariate effect specific to j^{th} responses category with the first reference category. The assumption that $\beta_1 = 0$ is an acceptable normalization that eliminates an indeterminacy in the model. This arises because probabilities sum to 1, so only J parameter vectors are needed to determine the $J+1$ probability (Galab et.al, 2002), so that $\exp(X_i\beta_1) = 1$, implying that the above generalized Eq. (5) is equivalent to:

$$\Pr(y_i=j | x_i) = P_{ij} = \frac{\exp(X_i\beta_j)}{1 + \sum_{j=1}^J \exp(X_i\beta_j)}, j = 1, \dots, J$$

And

$$\Pr(y_i=j | x_i) = P_{i1} = \frac{1}{1 + \sum_{j=1}^J \exp(X_i\beta_j)} \quad (6)$$

Where;

y = represents a polytomous outcome variable with codes ranging from 0..... J

The restriction that the J probabilities sum to 1 yields the likelihood of p_{i1}

That is $P_{i1} = 1 - \sum_j P_{ij}$.

We can compute J log-odds ratios, which are defined as in the binary logit model, specified as:

$$\ln \left[\frac{P_{ij}}{P_{i1}} \right] = x(\beta_j - \beta_1) = x\beta_j, \text{ if } j = 0 \quad (7)$$

This type of discrete outcome model can be estimated by applying the maximum likelihood method.

Marginal effects must be determined if reasonable conclusions about the direction and magnitude of the relationship between an independent and dependent variable in an MNL are to be drawn (Bowen and Wiersema, 2004). The marginal effects of a continuous independent variable are:

$$\frac{\partial \text{Pr}(\text{E})}{\partial \text{Pr}(\text{M})} = \frac{\partial \text{Pr}(\text{E})}{\partial \text{Pr}(\text{M})} = \frac{\partial \text{Pr}(\text{E})}{\partial \text{Pr}(\text{M})}$$

2.7 Variables used in the model and their definition

Five livelihood strategies groups were identified from the *haor* household and these were used as the dependent variables. It was assumed that the livelihood strategy choice is a function of several livelihood platform variables including a household's demographic factors, assets pentagon (human, natural, physical, financial, and social capitals) and location and geographical factors. Therefore, understanding the rural background of the *haor* inhabitants and reviewing the relevant literature, the explanatory variables as shown in Table 2 are selected for this study. The selected variables, their definitions, and expected relationships to livelihood strategy choices are summarized in Table 2.

Table 2
Variables used, their definition, and expected relation with livelihood diversification strategies

Dependent variable	Definition of variable	Expected relationship with livelihood strategies
Livelihood strategies $Y_1 = C$ $Y_2 = C+L$ $Y_3 = C+F$ $Y_4 = C+P$ $Y_5 = C+Off-Farm$	C = Crop farming C+L = Crop + Livestock farming C+F = Crop + Fish farming C+P = Crop + Poultry farming C+Off-farm = Crop + Off-farm activities (Wage earner, petty business/enterprise)	Five dominant livelihood strategies were found in the study areas to lead their livelihood
Explanatory variables		
Human capital		
Gender of HH head	The gender is main decision maker of a HH (Dummy, if sex of household head is male 1, otherwise 0)	Household headed by male are more likely to be involved in higher returning LDS
Age of HH head	Age of HH head in years	Younger HH heads are expected to adopt more profitable LDS
Education of HH head	Schooling years of HH head	Higher educated HH heads are more likely to be involved in higher returning LDS
Family size	Total HH member	Household with a bigger family size are expected to be adopt farm-based LDS
Dependency ratio	The dependency ratio is equal to the number of individuals aged below 15 or above 64 divided by the number of individuals aged 15 to 64, expressed as a percentage.	Household having lower dependency are expected engaged more diversified activities.
Agricultural training	HH head or other members of the HH have training related to agriculture (Dummy, if Yes = 1, No = 0)	HH having member/s with training related to agricultural training are expected to be involved in diversified agriculture
Skill development training	HH head or any member of the HH have training related to income generating activities (Dummy, if Yes = 1, No = 0)	HH having member/s with skill development training are expected to be involved in self-employed rural enterprise.
Natural capital		
Total land holdings	HH total own agricultural land (ha)	HH with small agricultural land holdings are likely to diverted in non-farm or wage earner-based livelihood strategy
Physical capital		
Household assets value	Estimated value of building, agricultural and non-agricultural assets own by HH (BDT.)	HH owning higher assets value are expected to engaged profitable LDS
Financial capital		
Access to credit	HH has getting loan facilities (Dummy; Yes = 1, No = 0)	HH having access to credit are more likely to start diversified activities
Income	HH's total annual income (BDT.)	HH having higher income more likely to start up diversified livelihood
Expenditure	HH's total annual expenditure (BDT.)	HH having higher expenditure less likely to be engaged in diversified livelihood
Social capital		
Membership of any organization	HH head or any member have been member of any group or organization (Dummy; Yes = 1, No = 0)	HH having member/s with membership in organization are expected to be involved in more profitable LDS
Infrastructures		
Home to road distance	Distance to nearest possible vehicle passable road (km)	HH residence closer to road is more likely to follow enterprise-oriented LDS

*LDS = Livelihood Diversification Strategy

Dependent variable	Definition of variable	Expected relationship with livelihood strategies
Home to market distance	Distance to nearest market place the HH usually used (km)	HH located closer to market places is more likely to be market oriented farm and non-farm LDS
Home to <i>haor</i> distance	Distance to nearest <i>haor</i> the HH usually effected by floodwater (km)	HH located closer to nearby <i>haor</i> is less likely to be engaged in diversified livelihood
Communication during the monsoon	Ways of communication during monsoon (Dummy; 1= Riverway, 2 = Roadway, and 3 = Both way)	The HH who use the river as a means of communication is more likely to be less diverse
Communication during the dry season	Ways of communication during dry season (Dummy; 1= Riverway, 2 = Roadway, and 3 = Both way)	HH who use the road as a mode of transportation is likely to be more diverse
Geographical factors		
Duration of waterlogged	The average number of months that the land was waterlogged	HH facing higher the number of months is likely to be less engaged in diversified strategies
Agro-ecology	Types of agricultural land in the <i>haor</i> areas (Dummy 1 = low land, 2 = medium high land, and 3 = high land)	HH in high land <i>haor</i> are expected to be involved in higher returning LDSs
*LDS = Livelihood Diversification Strategy		

3. Results

3.1 Household's income composition of different livelihood strategy

This study identified *haor* households into five livelihood strategy groups based on the *haor* household's existing livelihood activities. The Majority (34%) of the *haor* households are engaged in only crop farming, particularly rice agriculture, which is unprofitable but has to continue due to their forefathers' profession (Hoq et al., 2021a). Crop plus off-farm activities employed approximately 18% of households, followed by crop plus livestock farming (17.33%), crop plus fish farming (15.67%), and crop + poultry farming (15%) (Table 1). The sources of income for the various livelihood strategy groups are shown in Table 3. Rice, vegetables, oilseeds, maize, livestock, fisheries, poultry, wage/salary, petty business, vehicle driving, boating, power tiller operation, remittances, and land rent were all divided into fourteen categories. Crop farming is to be considered as a major component for all five categories of livelihood strategy group because about 80% of *haor* households depend on rice-based agriculture. Households in group Y1 exclusively depend on crop farming. Rice is the main crop for all types of livelihood strategies which contributes 91% of total income for group Y1 followed by 70% for group Y2, 57% for group Y3, 43% for group Y4, and 64% for group Y5. Households of the livelihood strategy group Y2 are involved in a combination of crop farming and livestock rearing which is the most lucrative earning source in the *haor* area and livestock alone contribute 28% of total income (Table 3). Households in groups Y3 and Y4 allocate their resources to fisheries and poultry farming in addition to crop farming respectively and fisheries and poultry farming alone contribute 34% and 50% of total income respectively. Commercial duck rearing by income group Y4 plays an important role to achieve such a percentage. Households in livelihood strategy group Y5 are the most diversified as they engage in different off-farm activities that in addition to crop farming. The households of this strategy generally pursued different off-farm activities such as wage and salary (13%), petty business (15%), vehicle driving (2%), and remittances (4%) which contribute altogether 34% of total annual income. The average annual income of different livelihood strategy groups is shown in Fig. 3. The highest annual average income is found in pursuing crop plus livestock farming (BDT.4,81,398) followed by crop plus fish farming (BDT. 4,09,622), crop plus poultry farming (BDT. 4,09,509), crop plus off-farm activities (BDT.3,05,433), and only crop farming (BDT. 235864). Hence, crop plus livestock farming is the most profitable livelihood strategy, on the other hand only crop farming is the least profitable livelihood strategy in the *haor* areas of Bangladesh.

Table 3
Source and accounting of income by livelihood strategies

Income sources	Y1= crop farming		Y2= Crop + Livestock farming		Y3 = Crop + Fish farming		Y4 = Crop + Poultry farming		Y5 = Crop + Off-farm activities	
	Tk./year/HH	% of total income	Tk./year/HH	% of total income	Tk./year/HH	% of total income	Tk./year/HH	% of total income	Tk./year/HH	% of total income
Crops										
Rice	214820	91	335868	70	235494	57	177689	43	196187	64
vegetables	6387	3	1105	0	10638	3	4644	1	1294	0
Oilseed	0	0	0	0	0	0	0	0	252	0
Maize	746	0	0	0	0	0	0	0	385	0
Livestock		0	134060	28		0		0	0	0
Fisheries	0	0	0	0	140723	34	0	0	0	0
Poultry	0	0	0	0		0	206776	50	0	0
Off-farm Activities		0		0		0		0		0
Wage/salary	0	0	0	0	0	0		0	40889	13
Petty business	0	0	0	0	0	0	0	0	46611	15
Driving	0	0	0	0	0	0	0	0	5130	2
Boating	0	0	0	0	0	0	0	0	1667	1
PT operating	0	0	0	0	0	0	0	0	1481	0
Remittances	0	0	0	0	0	0	0	0	11389	4
Land rent	13912	6	10365	2	22766	6	20400	5	148	0
Total income	235864	100	481398	100	409622	100	409509	100	305433	100

3.2 Descriptive statistics of the variables used in the model

The descriptive statistics of the livelihood platform variables used in the analysis were shown in Table 4. As for human capital, the empirical results revealed that the percentage of female-headed households is the lowest for only crop plus fish farming strategy (2%), while it was highest (15%) for the crop plus poultry farming activities. Hence, a female-headed household is likely to pursue crop plus off-farm activities though the overall percentage of female-headed households is less likely in all kinds of livelihood strategies because of religious and cultural barriers. The average age of the head of household is highest for crop plus fish farming strategy (48.32 years) whereas it is 47.08 years for crop plus livestock farming, 44.53 years for only crop farming, 43.85 years for crop plus off-farm activities, and 42.87 years for crop plus poultry farming. It suggests that crop farming, supplemented by poultry farming and off-farm activities, is preferred by the relatively young household heads. The result indicates that education plays a vital role in livelihood diversification strategy more willingly than crop plus poultry farming. The large family size is observed in the case of the crop plus livestock farming (6.56) followed by crop plus fish farming (5.79), crop plus poultry farming (5.47), crop plus off-farm activities (5.43), and only crop farming (5.14), which implies that a number of a family member in a household significantly influence the choice of livelihood diversification strategy. As for indicators of human capital, the agricultural and skill development training has a similar pattern in the case of diversifying livelihood strategy. However, for the dependency ratio, a divergent trend was found in the choice of livelihood diversification choice. As for natural capital, the total arable land holding is the highest (2.20 ha) for the household engaged in crop plus livestock farming, whereas it was lowest (1.12 ha) for crop plus off-farm activities signifying that less arable land holdings are important divers of household diversifying into off-farm activities. As for physical capital, the household assets value is highest for crop plus livestock farming (BDT. 6,25,324) followed by crop plus fish farming (BDT. 365645.1), crop plus poultry farming (BDT. 281090.6), crop farming (BDT.190226.70), and crop plus off-farm activities (BDT. 186207.80). The financial capital comprises access to credit, annual income, and annual expenditure indicators of a household livelihood diversification strategy. The result shows that the percentage of households in access to credit indicator is the highest (0.57) for only crop farming and the lowest (0.37) for crop plus off-farm activities. We observed a similar pattern in the other two financial capital indicators while annual income and annual expenditure are the least for pursuing only crop farming livelihood strategy. Membership of any organization is an important indicator of social capital which is a driver of pursuing the highest profitable livelihood strategy that is crop plus livestock farming. The infrastructure indicators home to road distance (0.58 km) are the least and the home to market distance (1.49 km), home to *haor* distance (1.45 km) is the highest for pursuing in crop plus off-farm activities, indicating as important accessibility determinants for livelihood strategy. On the other hand, communication system such as river way or roadway or both ways play an important role in the diversification of livelihood strategy. Due to its

geographical location, there is little difference in the value of the duration of waterlogging in the five types of the livelihood strategy group. The value of the agro-ecology indicators is the least for only crop farming, indicating the household in low land type agro-ecology mostly engaged in crop farming.

Table 4
Descriptive statistic of the livelihood platform variables

.Livelihood platform variable	Y ₁ =Only crop farming		Y ₂ = Crop + Livestock farming		Y ₃ = Crop + Fish farming		Y ₄ = Crop + Poultry farming		Y ₅ = Crop + Off-farm activities	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Human capital										
Gender of HH head	0.94	0.24	0.96	0.20	0.98	0.15	0.84	0.37	0.87	0.34
Age of HH head	44.53	11.85	47.08	10.47	48.32	10.86	42.87	11.20	43.85	12.43
Education of HH head	4.83	3.94	5.79	4.07	5.38	4.32	4.76	3.85	5.61	3.96
Family size	5.14	1.83	6.56	2.69	5.79	1.72	5.47	1.59	5.43	1.35
Dependency ratio	1.55	0.53	1.51	0.44	1.46	0.38	1.71	0.67	1.63	0.51
Agricultural training	0.33	0.47	0.52	0.50	0.49	0.51	0.33	0.48	0.24	0.43
Skill development training	0.25	0.44	0.44	0.50	0.51	0.51	0.27	0.45	0.20	0.41
Natural capital										
Total land holdings	1.27	1.23	2.20	3.41	1.53	1.29	1.14	0.87	1.12	0.86
Physical capital										
Household assets value	190226.70	191733.10	625324	478177.5	365645.1	290848.1	281090.6	159494.9	186207.80	136635.20
Financial capital										
Access to credit	0.57	0.50	0.56	0.50	0.45	0.50	0.40	0.50	0.37	0.49
Annual income	235864.10	172188.20	481397.5	527586.7	409621.9	215382.9	409508.9	226657.3	305433.30	122993.30
Annual expenditure	224450.80	110850.70	353241.7	157790.7	312561.2	142483.2	289806.00	94794.24	247817.20	75169.07
Social capital										
Membership of any organization	0.20	0.40	0.50	0.50	0.38	0.49	0.31	0.47	0.26	0.44
Infrastructures										
Home to road distance	0.69	0.32	0.80	0.70	0.73	0.42	0.74	0.28	0.58	0.30
Home to market distance	0.82	0.50	0.71	0.32	1.20	1.42	0.93	0.44	1.49	4.67
Home to <i>haor</i> distance	1.17	0.82	1.26	0.95	1.15	0.90	1.37	1.43	1.45	1.29
Communication during monsoon	1.36	0.77	1.35	0.76	1.34	0.76	1.22	0.60	1.31	0.72
Communication during dry season	2.17	0.66	2.06	0.73	2.23	0.73	2.04	0.80	2.35	0.62
Geographical factors										
Duration of waterlogged	5.00	1.54	5.40	1.18	5.15	1.43	5.22	1.18	5.13	1.37
Agro-ecology	1.47	0.52	1.75	0.76	1.81	0.65	1.53	0.63	1.59	0.66

3.3. Determinants of livelihood diversification strategies of *haor* households

The results of MNL regression were presented in Table 5. The study used only crop farming as a base category to assess the effect of predictor variables on the likelihood of a specific strategy choice. The results revealed that HH family size (0.259*), HH assets value (6.88e-06***), annual income (3.88e-06*), membership of any organization (1.517**), home to road distance (1.867**), riverway (1.992**) and both way (1.548**) (river and roadway) communication during the dry season, duration of the waterlogged condition (0.600**), and comparatively high land (3.645***) type agro-ecology than low land had the positive and significant impact on choosing crop plus livestock farming than only crop farming. Likewise, some other variables such as total land holdings (-1.151***) and home to market distance (-1.805**) had a negative and significant influence on choosing crop plus livestock farming. While comparing the crop plus fish farming with only crop farming, HH head age (0.039*), total land holdings (-1.025***), HH assets value (2.59e-06**), annual income (5.85e-06***), membership of any organization (0.887*), riverway communication during the dry season (1.290*), and comparatively high land (3.193***) type agro-ecology than low land had a significant influence on adopting the livelihood strategy of the crop plus fish farming. Similarly, households with a higher annual income (8.62e-06***), closer to the road connectivity (1.231*), riverway (1.924***) communication during the dry season rather than roadway, duration of the waterlogged condition (0.379**), and generally high land (2.704***) type agro-ecology compared to low land were more likely to adopt crop plus poultry farming rather than crop farming alone. On contrary, accessibility to credit (-1.087**), household total land holdings (-1.426***), had a negative and significant influence on adopting crop plus poultry farming as a livelihood strategy. Crop plus off-farm activities are a very important part of the subsistence household, which includes a diverse range of activities. The households of that group were positively and significantly influenced by the HH head education (0.128**), annual income (6.29e-06***), located closer to the *haor* (0.552*), and high land (2.637**) type agro-ecology compared to low land for adopting such kind of livelihood strategy. Household's total land holdings (-0.918***), and accessibility to credit (-1.169***) negatively and significantly influences the household's decision on adopting crop plus off-farm activities. Due to the ecological characteristics of the *haor* areas, infrastructural and geographical factors have had a greater impact on the adoption of livelihood diversification strategies than socioeconomic variables.

Table 5
Determinants of livelihood diversification strategies choice

Livelihood platform variables	Livelihood diversification strategies (Crop farming is a reference category)			
	Y ₂ = Crop + Livestock farming	Y ₃ = Crop + Fish farming	Y ₄ = Crop + Poultry farming	Y ₅ = Crop + Off-farm activities
Human capital				
Gender of HH head	1.427 (1.169)	1.636 (1.243)	-1.161 (0.778)	-0.649 (0.745)
Age of HH head	0.024 (0.025)	0.039* (0.021)	0.010 (0.022)	0.015 (0.019)
Education of HH head	0.088 (0.068)	0.083 (0.060)	0.067 (0.067)	0.128** (0.060)
Family size	0.259* (0.144)	0.001 (0.133)	-0.154 (0.148)	0.106 (0.134)
Dependency ratio	-0.017 (0.562)	-0.362 (0.466)	0.641 (0.419)	0.038 (0.410)
Agricultural training	0.209 (0.631)	-0.164 (0.564)	-0.036 (0.585)	-0.424 (0.542)
Skill development training	-0.243 (0.637)	0.658 (0.570)	-0.635 (0.621)	-0.751 (0.594)
Natural capital				
Total land holdings	-1.151*** (0.330)	-1.025*** (0.291)	-1.426*** (0.325)	-0.918*** (0.295)
Physical capital				
HH assets value	6.88e-06*** (1.28e-06)	2.59e-06** (1.21e-06)	1.42e-06 (1.39e-06)	-1.45e-06 (1.61e-06)
Financial capital				
Access to credit	-0.370 (0.547)	-0.728 (0.486)	-1.087** (0.487)	-1.169*** (0.434)
Annual income	3.88e-06* (2.30e-06)	5.85e-06*** (2.12e-06)	8.62e-06*** (2.13e-06)	6.29e-06*** (2.10e-06)
Annual expenditure	6.19e-06 (4.01e-06)	4.78e-06 (3.79e-06)	3.33e-06 (3.94e-06)	-1.39e-06 (3.96e-06)
Social capital				
Membership of any organization	1.517** (0.597)	0.887* (0.526)	0.489 (0.591)	0.777 (0.545)
Infrastructures				
Home to road distance	1.867** (0.847)	0.597 (0.693)	1.231* (0.758)	-0.929 (0.763)
Home to market distance	-1.805** (0.716)	0.414 (0.332)	-0.186 (0.477)	0.360 (0.335)
Home to <i>haor</i> distance	0.495 (0.421)	-0.100 (0.361)	(0.244) (0.356)	0.552* (0.324)

Livelihood platform variables	Livelihood diversification strategies (Crop farming is a reference category)			
	Y ₂ = Crop + Livestock farming	Y ₃ = Crop + Fish farming	Y ₄ = Crop + Poultry farming	Y ₅ = Crop + Off-farm activities
Communication during monsoon	River way is reference category			
Road way	-12.013 (1101.34)	-12.199 (736.12)	1.458 (2.171)	-1.500 (2.473)
Both way	-0.058 (1.025)	0.578 (0.874)	-1.140 (1.032)	-0.625 (0.866)
Communication during dry season	Road way is a reference category			
River way	1.992** (0.812)	1.290* (0.715)	1.924*** (0.704)	0.117 (0.774)
Both way	1.548** (0.663)	0.824 (0.552)	0.539 (0.575)	0.777 (0.501)
Geographical and ecological factors				
Duration of waterlogged	0.600** (0.264)	0.197 (0.182)	0.379** (0.212)	0.052 (0.144)
Agro-ecology	Low land is a reference category			
Medium high land	-0.824 (0.563)	0.469 (0.470)	-0.313 (0.475)	-0.318 (0.432)
High land	3.645*** (1.259)	3.193*** (1.216)	2.704*** (1.293)	2.637** (1.192)
Constant	-13.545*** (3.150)	-9.082*** (2.595)	-5.630*** (2.404)	-2.193 (2.026)

(Note: Number of obs. = 300, LR chi2 (96) = 297.20, Prob > chi2 = 0.0000, Log likelihood = -317.66279, Pseudo R² = 0.3187; ***, **, * indicates the 1%, 5% and 10% level of significance, figures in the parentheses indicate standard error)

3.4 Diagnostic of the model

The likelihood ratio statistics (-317.66279) of the multinomial logistic regression model as indicated by χ^2 statistics are highly significant ($P < 0.0000$), suggesting the model has strong explanatory power. The Hausman test for IIA, the seemingly unrelated postestimation procedure (SUEST), and the Small Hsiona based Husman test are used to diagnosis the model for the validity of the independence of the irrelevant alternatives (IIA) assumptions. The tests accept the null hypothesis of the independence of the livelihood strategy choice options, indicating that the multinomial logit (MNL) specification is appropriate to livelihood diversification strategy options practices by the *haor* household. It was evident from χ^2 value ranging from 0.119 to 3.342 in the case of the Hausman test (Appendix table A.1), χ^2 value ranging from 34.18 to 74.462 in the case of SUEST (Appendix table A.2), and χ^2 value ranging from 196.777 to 319.997 in case of Small Hsiona test (Appendix table A.3), which indicates there is no evidence that the independence of the irrelevant alternatives (IIA) assumption was violated. The higher the value of variance inflation factor (VIF), usually greater than 10, the more serious the multicollinearity problem. The VIF value of the independent variables is less than the critical value of VIF (10) which justifies that there is no multicollinearity among the variables (Appendix table A.4). Moreover, the correlation matrix indicated that there is no severe multicollinearity problem in the fitted model (Appendix table A.5).

3.5. Determinants of livelihood diversification strategy via marginal effect

We may depend on another powerful interpretative technique: marginal effects after multinomial logistic regression to further make the results to our sense. The marginal effects help us to inform the change in predicted probabilities due to a change in a particular predictor (Bowen and Wiersema 2004; Roy and Basu 2020). A negative and significant coefficient of the gender of HH head indicates a negative relationship between gender of HH head and probability of adoption of a specific livelihood strategy (Table 6). For example, an increase by one male-headed HH would lead to a 20% decrease in the likelihood of adopting crop plus poultry farming. Education is an important influencing factor in adopting new improved agricultural technologies or information, which increased agricultural productivity (Abid et al. 2015; Elahi et al. 2015). In our study, the significant positive coefficient of education of the household head shows that the probability of accessing crop plus off-farm activities increase by 1% with an increase of one year of schooling compared to crop farming. A

negative coefficient of family size indicates a negative relationship between family size and livelihood strategies choice (Khatun and Roy 2012), whereas a positive coefficient between dependency ratio and livelihood strategies indicates a positive relationship. Suppose, an addition by one individual in the household size is more likely to a decrease of 2.3 % in the adoption of livelihood strategy Y4 (crop plus poultry farming). On contrary, an increase by one individual in the household size is more likely to an increase of 2.2% in the adoption of livelihood strategy Y2 (crop plus livestock farming). In the case of dependency ratio, the livelihood strategy choice of Y4 (crop plus poultry farming) would increase by 7.2% with the increase of 1% dependency ratio. There is a positive association between livelihood strategy choice and skill development training indicates that a 1% increase of the skill development training would lead to a 10.7% increases probability of adopting livelihood strategy Y3 (crop plus fish farming). Total land holdings represent the total own cultivated land held by a farm household and may be taken as an indicator of wealth for a farm household. The results indicate that the total land area has negative and significant impacts on households involved in crop plus poultry farming. Therefore, a 1% increase in the own cultivated land is likely to decrease the probability of adopting the crop plus poultry farming as a livelihood strategy by 7.5%. The marginal effects of household assets value exhibit very different behavior depending on the outcome category (Amare and Simane 2017). An increase in the household assets value is likely to increase the probability of adopting the livelihood strategy Y2 (crop plus livestock farming), whereas it is likely to decrease the probability of adopting the livelihood strategy Y5 (crop plus off-farm activities). The result of access to credit shows that keeping the effect of other variables constant, the likelihood of choosing crop plus off-farm activities is 8.8% lower than for farmers without credit facilities. There is a positive relationship between household's annual incomes and the likelihood of accessing crop plus poultry farming and crop plus off-farm activities indicating that a 1% increase of the annual income would likely increase the adoption of the crop plus poultry farming and crop plus off-farm activities by 6.10e-05% and 3.40e-05% respectively. Membership of any organization showed a positive and significant relationship with the adoption of the crop plus livestock farming indicating a unit increase of the membership facilities in an organization increases the probability of crop plus livestock farming by 7.7%. Home to road distance is positively related to the crop plus livestock farming and crop plus poultry farming, and negatively related to the crop plus off-farm activities. It indicates a 1% increase of the home to road distance results in an increase of crop plus livestock farming and crop plus poultry farming by 11.9% and 10.4% respectively. Whereas a decrease of 18% in the probability of adopting crop plus off-farm activities with the increase of 1% home to road distance. Similarly, home to market distance has a positive association with the crop plus fish farming, crop plus off-farm activities, and a negative association with the crop plus livestock farming. Home to *haor* distance shows positive and significant evidence with the adoption of the crop plus off-farm activities indicating a 1% increase of the home to *haor* distance would lead to an increase of a 5.5% in the probability of choosing crop plus off-farm activities as a livelihood diversification strategy (Hoq et al. 2021b). Roadway communication during monsoon significantly and negatively influences the *haor* household in adopting livelihood diversification compared to its base category river way communication. The results indicate that a 1% increase in roadway communication decreases the probability of adopting crop plus fish farming by 14.5%. On the contrary, riverway and both way (road and riverways) communication during dry season significantly and positively influence the *haor* household in adopting crop plus poultry farming and crop plus livestock farming respectively. It indicates that one unit increase in the riverway communication increases the probability of choosing crop plus poultry farming by 15.2% and 'increases the probability of choosing crop plus livestock farming by 7.9% as a livelihood strategy. Unexpectedly duration of waterlogged significantly and positively influences the crop plus livestock livelihood strategy which indicates one unit (month) increase in the duration of waterlogged is likely to increase the probability of crop plus livestock farming by 3.4% (Hoq et al. 2021b). Hence, it may be due to rearing livestock in household home yard which is physically observed during the data collection. Farmers living in different agro-ecological settings used different livelihood strategies as a measure of different adaptation strategies. Farming in medium high land agro-ecology significantly decreases the probability of crop plus livestock farming by 6.6% and significantly increases the probability of adopting crop plus fish farming by 8.3% compared with farming in low land agro-ecology.

Table 6
Marginal effect after multinomial logistic regression (MNL) of livelihood strategy model

Livelihood platform variable	Y ₂ = Crop + Livestock farming	Y ₃ = Crop + Fish farming	Y ₄ = Crop + Poultry farming	Y ₅ = Crop + Off-farm activities
Human capital				
Gender of HH head	0.095 (0.084)	0.173 (0.120)	-0.160*** (0.060)	-0.095 (0.071)
Age of HH head	0.0004 (0.002)	0.003 (0.002)	-0.0006 (0.002)	0.0004 (0.002)
Education of HH head	0.002 (0.004)	0.002 (0.005)	-0.0003 (0.006)	0.010* (0.006)
Family size	0.022** (0.009)	-0.006 (0.011)	-0.023* (0.013)	0.013 (0.014)
Dependency ratio	-0.003 (0.040)	-0.053 (0.044)	0.072** (0.036)	-0.006 (0.043)
Agricultural training	0.027 (0.043)	-0.014 (0.053)	0.008 (0.052)	-0.048 (0.058)
Skill development training	-0.018 (0.042)	0.107** (0.050)	-0.053 (0.053)	-0.082 (0.062)
Natural capital				
Total land holdings	-0.025 (0.018)	-0.027 (0.021)	-0.075*** (0.025)	-0.033 (0.028)
Physical capital				
Household assets value	4.62e-07*** (6.36e-08)	7.99e-08 (8.76e-08)	4.05e-09 (1.08e-07)	-3.47e-07** (1.61e-07)
Financial capital				
Access to credit	0.025 (0.037)	-0.020 (0.044)	-0.054 (0.042)	-0.088** (0.045)
Annual income	-9.33e-08 (1.15e-07)	2.01e-07 (1.40e-07)	4.98e-07*** (1.37e-07)	3.30e-07* (1.84e-07)
Annual expenditure	3.08e-07 (2.12e-07)	2.94e-07 (2.72e-07)	1.62e-07 (2.97e-07)	-4.33e-07 (3.98e-07)
Social capital				
Membership of any organization	0.077** (0.038)	0.025 (0.045)	-0.019 (0.049)	0.041 (0.055)
Infrastructures				
Home to road distance	0.119** (0.056)	0.003 (0.061)	0.104* (0.063)	-0.180** (0.080)
Home to market distance	-0.156*** (0.050)	0.093*** (0.028)	-0.005 (0.041)	0.060** (0.029)
Home to <i>haor</i> distance	0.031 (0.028)	-0.042 (0.033)	0.002 (0.031)	0.055* (0.032)

(Note: ***, **, * indicates the 1%, 5% and 10% level of significance, figures in the parentheses indicate standard error)

Livelihood platform variable	Y ₂ = Crop + Livestock farming	Y ₃ = Crop + Fish farming	Y ₄ = Crop + Poultry farming	Y ₅ = Crop + Off-farm activities
Communication during monsoon	River way is reference category			
Road way	-0.172 (0.254)	-0.145*** (0.020)	0.420 (0.390)	-0.141 (0.098)
Both way	-0.002 (0.072)	0.110 (0.102)	-0.088 (0.056)	-0.058 (0.075)
Communication during dry season	Road way is reference category			
River way	0.079 (0.057)	0.028 (0.064)	0.152** (0.074)	-0.083 (0.057)
Both way	0.079* (0.045)	0.015 (0.048)	-0.011 (0.043)	0.043 (0.055)
Geographical factors	Low land is reference category			
Duration of waterlogged	0.034* (0.019)	-0.005 (0.017)	0.022 (0.019)	-0.016 (0.016)
Agro-ecology	Low land is reference category			
Medium high land	-0.066* (0.037)	0.083** (0.042)	-0.019 (0.041)	-0.029 (0.045)
High land	0.136* (0.080)	0.074 (0.074)	0.022 (0.087)	0.066 (0.094)
(Note: ***, **, * indicates the 1%, 5% and 10% level of significance, figures in the parentheses indicate standard error)				

4. Discussion

The study categorizes a household's entire livelihood activities into five livelihood strategies groups pursued in the study areas of the wetland *haor* ecosystem of Bangladesh. Those strategies mainly consist of various agricultural production practices and non-farm activities (e.g., petty business, wage labor, migratory work, etc.), which are consistent with the findings of Jiao et al. (2017) in rural Cambodia. This diverse set of livelihood approaches and income composition of each livelihood strategy suggest that rural household mostly involves in multiple income-earning activities, which are essential for survival and for reducing risk and uncertainty in the production process of the unfavorable ecosystem in rural areas (Liu and Lan 2015; Jiao et al. 2017; Ellis 1998 2000). Income from the crop sector contributes the largest share to household total income, and income from rice production is still indeed the primary source of farm income for *haor* households, especially for the subsistence farmer. These findings are closely related to the findings of Rigg et al. (2016) and Gautam and Andersen (2016) in the case of East and Southeast Asia's smallholders. Previous studies reported that about 80% of *haor* areas are covered by *boro* rice cultivation and another 10% is covered by transplanted Aman rice (Huda 2004; Khan et al. 2012; Hoq et al. 2021a). The results revealed that most of the *haor* households engaged in agriculture-based livelihood, especially in rice crop farming (only crop farming livelihood strategy), and they earn low and sometimes negative returns from crop farming but cannot stop due to financial barriers and finding no alternative way; these findings are supported by Alamgir et al. (2020). The most lucrative livelihood strategy is found in pursuing crop plus livestock farming that generated higher income from crop and livestock sales. This result agrees with Khatiwada et al.'s (2017) findings for rural household livelihood strategies in central Nepal. The study also identified some other profitable livelihood options such as crop plus fish farming, crop plus poultry farming, and crop plus off-farm activities in *haor* areas of Bangladesh which also supported by some previous studies (Islam 2011; Islam et al. 2012; Parvin and Akteruzzaman 2013; Sunny et al. 2020; Uddin et al. 2019). These livelihood strategies require a significant amount of capital investment to start up that is why the majority of them are unable to participate; such findings are in line with Gautam and Andersen's findings (2016). The asset-poor *haor* households are unable to overcome the entry barriers to high return sectors and are confined to low return sectors that cannot contribute significantly to their well-being (Singh et al. 2018). Some innovative farmers diverse their livelihood activities into livestock, fisheries, and poultry farming and off-farm activities along with crop farming to combat natural disasters in their production process. Age and education of the household head and dependency ratio are most influencing human capital in adopting the higher returning livelihood strategies (Xu et al. 2019) which has consistent with the present study. The positive and significant coefficient of the age variable indicates that the elderly have enough capacity to accumulate assets to enable them to invest and diversify their activities into crop plus fish farming, which is consistent with the finding of Rahut et al. (2017) for diversifying rural livelihood into non-farm sectors in Bhutan. Similarly, the positive and significant coefficient of the HH head education reflects that higher education is likely to develop more skilled and capable entrepreneurs that influence them to adopt crop plus off-farm activities; these findings are also supported by the previous studies (Khatun and Roy 2012; Khatiwada et al. 2017; Rahut et al. 2017). The family size determinant was found to be positively related to crop plus livestock farming, which is contrary to the results of Khatun and Roy (2012) and Gebru et al. (2018). One probable explanation is that when the number of members of a household increased, the likelihood of them becoming

more involved in livestock farming keeps growing as well. The results of the natural capital indicated that there is a negative and significant relationship between total landholding and the choice of adopting all higher returning livelihood strategies. The argument is that low return from subsistence farming alone cannot sustain the smallholder's rural livelihood which compels them to generate higher income from limited farm size through diversifying their activities into more than only crop farming (Khatiwada et al., 2017). Therefore, the *haor* households with large landholdings do not have a surplus labor force that can be able to diversify (Rahut et al. 2017). Physical capital found a positive and significant relationship between household asset value (farm and non-farm) and the two most profitable livelihood diversification strategies: crop plus livestock farming and crop plus fish farming. It is true that households with a high initial livelihood asset indeed have greater freedom of choosing and diversifying their livelihood into higher-returning crop plus livestock and crop plus fish farming and benefited most. These findings are consistent with the findings of Adepoju and Obayelu (2013), Loison (2015), and Gebru et al. (2018). The support of financial capital is very important to start up a new livelihood strategy (Khatiwada et al. 2017; Xu et al. 2019). Unfortunately, the credit facility is negatively related to adopting all livelihood diversification strategies and significantly influences the crop plus poultry and crop plus off-farm livelihood strategies. The result, however, contradicts the findings of Gebru et al. (2018) and Davies (2004). The possible explanation could be that the *haor* household may not be able to utilize the credit properly in the livelihood activities. Sunny et al. (2020) also found an easy source of informal credit with unfavorable interest, terms, and conditions for the *haor* household, which aggravate their poverty level. Household annual income from the respective livelihood strategies positively and significantly influences all livelihood diversification strategies. Analysis reveals a positive and significant relationship between membership of any organization (social capital) and livelihood strategies Y2 (crop plus livestock farming) and Y3 (crop plus fish farming), which is consistent with the findings of Khatun and Roy (2012) and Khatiwada et al. (2017). Rural infrastructure, particularly household home to road, market, and *haor* distance were found significant determinants influencing livelihood strategy choice. The results indicate an increase in the distance from home to the road increases the probability of adopting the crop plus livestock farming and crop plus poultry farming. It could be due to the availability of land and grassland which is favorable for crop production and livestock grazing as well as poultry farming (Rabby et al. 2013). Similarly, greater distance from home to *haor* enables *haor* household to adopt the higher returning livelihood strategy, especially significantly influence in adopting the crop plus off-farm activities. On the other hand, proximity to market place is favorable for crop plus livestock farming because households being closer to market place can easily sell their livestock products at a higher price (Khatiwada et al. 2017). Riverway and both-way (river and roadways) communications are significantly and positively related to livelihood strategy Y2 (crop plus livestock farming) since the river and both-way communication promote livestock rearing and grazing. The livelihood strategy Y3 (crop plus fish farming) is positively and significantly influenced by riverway communication during the dry season, which may be due to their ability to connect with the marketplace for fish marketing with low transportation costs (Sunny et al. 2020). In line with our expectation, riverway communication is to be positively and significantly influence the livelihood strategy Y4 (crop plus poultry farming). Riverway communication is one of the most influential factors for poultry farming, particularly duck rearing, in the rural *haor* areas of Bangladesh (Islam et al. 2012). Geographical and ecological characteristics such as waterlogged duration and agro-ecology have a positive and significant impact on the choice of a livelihood strategy (Rahman and Hickey 2020). Opposite of our expectation, the livelihood strategy Y2 (crop plus livestock farming) is positively related to the duration of waterlogging (months), possibly due to providing more effort during monsoon as it is the lean season for crop farming. As expected, the duration of waterlogging was found to be one of the important determinants of adopting a livelihood strategy Y4 (crop plus poultry farming), because duck rearing is required of persistent water for a long time (Islam et al. 2012; Khanum and Mahadi 2015). According to the study, highland households are more likely than lowland households to adopt strategic livelihood diversification in the wetland ecosystem (Islam et al. 2011).

5. Conclusion And Recommendations

The study looked at the various livelihood strategies practiced by *haor* households as well as the major determinants that influence the choice of those livelihood diversification strategies in the study areas. Flash floods, floods, droughts, riverbank erosion, and embankment breach are the extreme nature-induced disasters that caused increasing harm to the poor in crop production and livelihood diversification was the indigenous strategy to adapt to climate-induced vulnerabilities. Crop farming has been identified as the primary economic activity and source of income for many households, even though it is unprofitable. In addition to crop farming, which is commonly done by rural *haor* households, the study discovered four viable livelihood diversification alternatives. Rice is the primary crop for all types of livelihood strategies which contributes alone a range of 43–91% of the total household income of all livelihood strategy groups. The crop plus livestock strategy group (Y2) has gained the highest annual average income followed by crop plus fish (Y3), crop plus poultry (Y4), crop plus off-farm activities (Y5), and only crop farming (Y1). Therefore, crop production supplemented by livestock farming or fish farming or poultry farming (duck rearing), or off-farm activities could be an important means of subsistence. Multinomial logistics regression results showed that household's head age and education, dependency ratio, total land holdings, household assets value, access to credit, annual income, membership of any organization, home to road, market, and *haor* distance, river, and both way communication during the dry season, duration of waterlogged, and agro-ecology are the major determinants that significantly influence the choice of higher returning livelihood strategies. Furthermore, marginal effect analysis revealed that household's head gender and education, family size, dependency ratio, skill development training, land holdings, household assets value, access to credit, annual income, membership of any organization, home to road, market, and *haor* distances, roadway communication during monsoon, river and both way communication during the dry season, duration of waterlogged, and medium high land type agro-ecology are the significant determinants of choosing better-paying livelihood strategies which measure the percentage change in probability of a particular choice being made to a unit change of a particular variable. Therefore, it is recommended that such significant determining factors of livelihood strategy choice can be promoted through policy interventions that have a significant impact on sustainable livelihood. In addition, the government should put in place effective policies to make livestock, fisheries, and poultry easier for the *haor* community. Community-owned grazing land, such as community grasslands, is a better choice for safeguarding livestock farmers in the *haor* areas. Fishing is a seasonal business that can only be undertaken for a few months of the year, leaving people unemployed for the rest of the year and allowing them to diversify their activities. The *haor* basin, on the other side, has enormous potential for commercial duck farming. The availability of natural duck feeding sources and a tradition of duck farming in the *haor* region are the factors that may be prompted for developing duck farming in this area. However, these sustainable strategies require enormous capital investment, which is

why most of them cannot participate in these livelihood diversification strategies. For ensuring participation in these livelihood opportunities governments, NGOs, and other development organizations should initiate different policies and programs such as credit facilities for assets accumulations, skill development training, and training for improved fisheries, livestock and poultry farming, etc.

Declarations

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Figures

Figure 1

a) indicates the location of the study areas (three districts) in the Bangladesh map and (b-d) indicates the selected six upazilas from three districts.

(Source: Adopted from Khatiwada et al. 2017; Carney1998; Soltani et al. 2012 and Babulo et al. 2008)

Figure 2

Conceptual sustainable livelihood framework (SLF)

Figure 3

Source of income by different livelihood strategies group

Supplementary Files

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